ORNELL UNIVERSITY ANNOUNCEMENTS

NGINEERING

SEPTEMBER 1959

OLLEGE OF ENGINEERING

THE ACADEMIC CALENDAR

1959–1960

Sept. 18	F	Freshman orientation
Sept. 21	M	Registration, new students
Sept. 22	T	Registration, old students
Sept. 23	W	Instruction begins, 1 p.m.
Nov. 11	W	Midterm grades due
		Thanksgiving recess:
Nov. 25	W	Instruction suspended, 12:50 p.m.
Nov. 30	M	Instruction resumed, 8 a.m.
		Christmas recess:
Dec. 19	S	Instruction suspended, 12:50 p.m.
Jan. 4	M	Instruction resumed, 8 a.m.
Jan. 23	S	Instruction ends
Jan. 25	M	Second-term registration, students in residence
Jan. 26	T	Examinations begin
Feb. 3	W	Examinations end
Feb. 4	Th	Midyear recess
Feb. 5	F	Midyear recess
Feb. 6	S	Registration, students not in residence in fall term
Feb. 8	M	Second-term instruction begins
Mar. 26	S	Midterm grades due
		Spring recess:
Mar. 26	S	Instruction suspended, 12:50 p.m.
Apr. 4	M	Instruction resumed, 8 a.m.
May 28	S	Instruction ends
May 30	M	Examinations begin
June 7	T	Examinations end
June 13	M	Commencement Day

COLLEGE OF ENGINEERING

SCHOOL OF CIVIL ENGINEERING
SIBLEY SCHOOL OF MECHANICAL ENGINEERING
SCHOOL OF ELECTRICAL ENGINEERING
SCHOOL OF CHEMICAL AND METALLURGICAL ENGINEERING
GRADUATE SCHOOL OF AERONAUTICAL ENGINEERING
DEPARTMENT OF ENGINEERING PHYSICS
AGRICULTURAL ENGINEERING

SEPTEMBER, 1959

CORNELL UNIVERSITY ANNOUNCEMENTS

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COLLEGE OF ENGINEERING

ORGANIZATION AND HISTORY

THERE ARE two principal types of engineering colleges in America today. One is a self-contained unit stressing science and technology, often referred to as a technological institute. The other, of which the College of Engineering at Cornell is an example, is that subdivision of a university which emphasizes technological education but, in the development of its curricula, is able to call upon the educational resources of other programs of professional and nonprofessional study. At Cornell these other areas of study include agriculture, architecture, arts and sciences, business and public administration, home economics, hotel administration, industrial and labor relations, and law.

Engineering has had an important place in the program of Cornell University from the beginning. The Federal Land Grant or Morrill Act of 1862, which supplied a considerable proportion of the University's original endowment, specified that a leading object of the institution should be to teach "such branches of learning as are related to. . .the mechanic arts"; and this provision was in perfect accord with the ideals of the founder and of the first president. Both Ezra Cornell, the practical man of affairs who had amassed a fortune in the Western Union Telegraph Company, and Andrew D. White, the brilliant scholar and educator who had carefully analyzed contemporary higher education in America and in Europe, believed in the equal dignity of scientific and classical studies and determined to put the practical arts, such as engineering, on the same plane with the humanities. This program was considered revolutionary when announced at the University's opening in 1868. That it has since been generally adopted by American universities indicates the soundness of the basic Cornell idea that instruction in engineering should be given on a high professional level. The College of Engineering still adheres firmly to this policy.

Mechanical engineering and civil engineering have been strong divisions of the University since its foundation. In 1883 Cornell opened courses in electrical engineering, among the first to be offered anywhere in America; and in 1919, when the Board of Trustees formed the present College of Engineering, the School of Electrical Engineering was established. Courses in chemical engineering were organized in 1931, and seven years later the School of Chemical Engineering was established to supervise the curriculum which leads to the degree of

Carpenter Hall (1957) contains the Engineering Library and the administrative offices of the College.

Bachelor of Chemical Engineering. A course in metallurgical engineering has now been added, and the name of the school has been changed to the School of Chemical and Metallurgical Engineering. In 1946 the Graduate School of Aeronautical Engineering was founded. The same year the Department of Engineering Physics was started. Finally, in 1952, a professional curriculum in agricultural engineering was established as a joint program with the College of Agriculture.

CURRICULA AND DEGREES

UNDERGRADUATE STUDY is available in these divisions of the College: The School of Civil Engineering, the Sibley School of Mechanical Engineering, the School of Electrical Engineering, the School of Chemical and Metallurgical Engineering, and the Department of Engineering Physics. A course in professional agricultural engineering is given in cooperation with the College of Agriculture.

GRADUATE STUDY is available in the Engineering Division of the Graduate School of the University (including the schools and departments listed above and the Department of Mechanics and Materials) and in the Graduate School of Aeronautical Engineering.

Cornell University confers the following degrees on the successful completion of undergraduate courses of study in the College of Engineering: Bachelor of Civil Engineering (B.C.E.); Bachelor of Mechanical Engineering (B.M.E.); Bachelor of Electrical Engineering (B.E.E.); Bachelor of Chemical Engineering (B.Ch.E.); Bachelor of Metallurgical Engineering (B.Met.E.); Bachelor of Engineering Physics (B.Eng.Phys.); Bachelor of Agricultural Engineering (B.Agr.E.).

The general degrees of Master of Science (M.S.) and Doctor of Philosophy (Ph.D.) are available in all the various divisions of engineering and in related fields in the physical sciences. These degrees require advanced work in major and minor subjects, as well as the completion of individual research. They are granted by the University on the recommendation of the faculty of the Graduate School. In addition, the following professional graduate degrees are available: Master of Chemical Engineering (M.Ch.E.), Master of Civil Engineering (M.C.E.), Master of Electrical Engineering (M.E.E.), Master of Industrial Engineering (M.I.E.), Master of Mechanical Engineering (M.M.E.), and Master of Metallurgical Engineering (M.Met.E.). These degrees are administered by the Engineering Division of the Graduate School and are awarded on the recommendation of the faculty of the Graduate School upon the completion of specific curricula in the various schools of the College of Engineering.

The degree of Master of Aeronautical Engineering (M.Aero.E.) is granted on the recommendation of the faculty of the Graduate School of Aeronautical Engineering.

OBJECTIVES OF ENGINEERING AT CORNELL

The purpose of engineering at Cornell is to create a balanced educational experience that will serve the individual over the whole range of his future vocational and personal progress. In his studies, the Cornell engineer builds upon a broad background of basic and applied science, enabling him to achieve technical competence in advanced fields of modern technology while avoiding narrow specialization. This fundamental approach has enabled numerous engineering graduates to gain distinction outside their original fields of study in the co-ordination of complex enterprises involving varied technical activities.

In addition to the formal academic work that occupies the major part of a student's time, there are the opportunities afforded by University life, which can be a distinctive influence on his personal development. To take advantage of these opportunities should be part of the plan of every student, if he is to make his college experience most effective. The Cornell engineer can study and live in the vital atmosphere of a University community dedicated to teaching and advancing knowledge over a wide spectrum of human endeavor. The graduate therefore leaves Cornell not only with the results of his own academic training, but also with the intellectual and spiritual stimulation of a University known for its climate of freedom and its regard for individual values and responsibility.

For students with the necessary aptitude, character, and determination, the College of Engineering aims to provide the opportunities for learning, inspiration, and personal development that contribute to notable engineering careers.

THE CORNELL FIVE-YEAR PROGRAM

Cornell has pioneered in the five-year undergraduate course for the Bachelor's degree in engineering. The five-year program enables an engineering student to develop a breadth of technical and human perspective to meet the changing requirements of the engineering profession.

Undergraduate study in engineering at Cornell reflects the accelerating technical advancement of our times. Many of the traditional distinctions of engineering are rapidly breaking down as the applications for systems engineering, synthesizing several technical disciplines, receive increased emphasis. Hence, those areas of basic science and applied engineering science that form a common background for all specialized fields are a major part of the undergraduate program. Entirely new fields have become important dimensions of modern engineering in recent years. The Cornell engineering student has an

opportunity to receive instruction in the principles of such subjects as nuclear engineering, operations research, gas dynamics, solid state phenomena, and information theory. The social sciences and the humanities, gaining increased significance for the engineer, who must assume greater responsibility for leadership in the complex society of tomorrow, are important elements of undergraduate courses of study.

Because the student in the Cornell five-year program can develop a strong foundation of mathematics, basic science, and fundamental engineering science in the early years of his course, he can go further in the nature and depth of advanced subjects he pursues in his fourth and fifth years. Throughout the five years, progressive sequences of nontechnical subjects can be developed paralleling technical courses. This enables the student to utilize his growing experience and intellectual maturity to obtain the greatest satisfaction and meaning from his liberal arts courses. By undertaking a unified program of engineering and liberal studies in the stimulating and cosmopolitan setting of the University, the Cornell engineering student can find varied opportunities for individual educational achievement.

Students desiring to continue their engineering education at the graduate level can use their time as undergraduates more efficiently in the five-year program. The thorough grounding in mathematics and science and the opportunity for developing a sound foundation in advanced technical fields available in the five-year program are valuable assets for graduate study.

The Cornell engineering curricula are composed of four principal categories of subjects: (1) basic science (mathematics, physics, chemistry); (2) applied engineering science (mechanics, properties of materials, dynamics, electrical theory, etc.); (3) applied technology (structural design, hydraulics, industrial engineering, electronics, power, chemical operations, and similar subjects related to modern engineering practice); (4) general, managerial, and liberal studies (English, history, management, psychology, public speaking, economics, law, and additional subjects the student may elect in the various divisions of the University).

While the distribution of courses from these categories varies with each curriculum, in general the basic science and applied engineering science are presented in the first half and applied technology in the second half. The nontechnical subjects are scheduled throughout the five years. In some curricula the majority of required or elective courses in liberal arts or other nontechnical fields is prescribed; in others the majority is elective. In all curricula a student will spend the equivalent of about one year of his five on subjects outside the fields of engineering, mathematics, and science.

An outstanding faculty is responsible for the effectiveness of the five-year program. Faculty members, by their informal guidance of

individual students, their teaching methods in the classroom, and their contributions to research in a wide variety of fields, give inspiration and direction to the high caliber of engineering scholarship at Cornell. It has been the policy of Cornell engineering that all professors meet with undergraduate students.

In evaluating the time and expense associated with the fifth year of undergraduate study, the prospective engineering student should remember that his college work is formal preparation for a forty- or forty-five year professional career. Considering the revolutionary progress of technology that is certain to occur in the years ahead, an extended college program designed to meet the requirements of future progress is of major value for personal advancement in an engineering career.

THE ROLE OF ENGINEERING

The role of the engineer in this age of technological and social change is increasing in the breadth of its implications for the whole of society, as well as in the depth of its requirements for technical competence. Technology has radically rearranged human life. The engineering profession is itself undergoing continuing development. To prepare himself effectively for the challenging engineering problems of tomorrow, the prospective engineering student must select a college program that will be a sound foundation for a career in shaping tomorrow's technology.

Almost every dimension of modern living is touched by the work of engineers. Jet air transportation and mass communication have shrunk man's scale of time and vastly increased his mobility. Innovations in cultivating, processing, and preserving agricultural products have contributed to the development of an abundant food supply in many parts of the world. New fabrics for clothing and a variety of new materials for buildings have resulted from engineering research. Medicine, in alliance with technology, has increased the span of life itself and in so doing has raised the standards of human health.

Some of the greatest advances have been made in the generation of power. Engineering has enabled man to harness enormous sources of energy. Because the amount of physical labor necessary to obtain the necessities of life is constantly decreasing, men have growing opportunities for richer, more rewarding living. The production and consumption of power is a key factor in the future impact of industrialization on raising the material living standards of underdeveloped countries. In this area, engineering problems are inseparable from complex social problems.

Concurrently with his leadership in technological progress, the engineer will be called upon to assume major responsibilities in public

affairs. Engineering will directly affect public policy in such areas as determining how the nation's economic resources will be applied to national security; defining the role of the government in supporting pure research; establishing programs to assist underdeveloped areas of the globe; and implementing the flow of information about technical problems to the voting public in such form that they can make intelligent decisions on issues involving science and engineering. The profession as a whole must communicate the meaning of its accomplishments and goals to citizens in a democratic society.

Man has now crossed the threshold of the space age. As he stands at the edge of this great frontier challenging almost every branch and function of engineering, he realizes that the impact of technology in modern life is today just a modest preview of the role of engineering tomorrow.

The rapidity and scope of technological change mean it is no longer possible for engineering colleges to teach today's practical skills as an adequate educational background for the future. Rather, modern engineering education must emphasize the fundamental bases for understanding the physical world and must encourage sensitivity to human needs and aspirations. While the traditional characteristics of objectivity, precision, and disciplined persistence must still be cultivated, the engineer of tomorrow must be educated to apply new types of analytical approaches in order to solve the new kinds of problems he will encounter.

THE RELATIONSHIP OF ENGINEERING AND SCIENCE

The engineer *applies* the principles of science in the design and operation of products and processes to serve men. Thus, while the engineer needs to have a working knowledge of basic science, he translates his comprehension into concrete forms. He is essentially a *builder,* whose professional activities may assume a diversity of forms—engineering research, preliminary design, product development, planning for production, or management of industrial enterprises. Science is the foundation upon which the engineer builds.

In a recent statement, the President's Scientific Advisory Committee clearly expressed the fact that the scientist and engineer each play an important role on the same team: "The *scientist* is one who seeks to extend the boundaries of knowledge in his chosen field. The *engineer* has the task of combining the knowledge of science with his knowledge and awareness of the needs and limitations of human beings and of a human society to develop and create new things for human use.... While scientists have uncovered the basic knowledge, it is the engineers who have created the tangible tools, materials, and products that have

revolutionized our daily lives, our community living, and our national defense."

Obviously, the engineer must be well versed in science and not infrequently must be prepared to refine the scientific knowledge to shape it to his needs. But he must have additional capabilities not usually a part of strictly scientific training: he must know how to proceed in the techniques of manufacture, of construction, of operation; he must deal with matters of finance, of labor relations, of economic requirements, of public policy.

Because his works form a focal point at which the financial, material, and human resources of society are interrelated, the engineer is concerned with the *means* of dynamic civilization. The work of the engineer involves a unique conceptual process of balancing functional performance with costs, reliability, serviceability, and structural efficiency. Thus he considers not only if his creation will work, but how it can be built, who will use it, and the environmental conditions under which it will operate.

ADMISSION

PROCEDURE AND REQUIREMENTS

All correspondence concerning admission to the College of Engineering should be addressed to the Director of Admissions, Edmund Ezra Day Hall, Cornell University, Ithaca, New York, who will forward the necessary application blanks on request.

Detailed information concerning the requirements for admission, including health requirements, and methods of procedure are outlined in the University's *Announcement of General Information,* which every candidate for admission should read carefully and which can be obtained by writing to the Cornell University Announcements Office.

Entrance subjects must include English (four units), elementary and intermediate algebra (two units), plane geometry (one unit), and trigonometry (one-half unit). A foreign language (two units) *or* history (two units); advanced algebra (one-half unit) *or* solid geometry (one-half unit); and chemistry (one unit) *or* physics (one unit) must also be offered. It is strongly recommended that at least three of the elective units offered to make up the balance of sixteen be in language or history. Applicants are also advised to offer advanced algebra rather than solid geometry, when a choice is possible. Candidates for admission to the School of Chemical and Metallurgical Engineering are required to have chemistry (one unit).

Each candidate for admission is required to take the Scholastic Aptitude Test of the College Entrance Examination Board and to request the Board to report the results to the Director of Admissions, Cornell

University. Candidates are urged to take the test in January of their senior year.

Applicants must also take the CEEB achievement tests in advanced mathematics and either physics or chemistry, except that candidates for Chemical Engineering must take the test in chemistry. The achievement tests must be taken not later than March of the year of the applicant's entrance to college.

The number of applicants admitted to the several schools of the College of Engineering is limited by the facilities available for adequate instruction. The committees on admissions in each of the schools will exercise discretionary power in selecting those to be admitted. Preference will be given to those candidates whose academic preparation and personal character indicate fitness to pursue with success the course of study to be undertaken, who show evidence of professional promise, and who complete the filing of their entrance credentials in ample time for the committee to give thorough consideration to their qualifications.

CHOICE OF CURRICULUM

Every applicant for admission is asked to designate the branch of engineering he wishes to study, namely, civil engineering, mechanical engineering, electrical engineering, chemical engineering, metallurgical engineering, or engineering physics. Each branch has its own curriculum which carries its own professional degree.

The first year of study is essentially the same for all branches and includes mathematics, physics, chemistry, English, and appropriate courses in descriptive geometry or drafting. This similarity of the curricula in the freshman year makes it possible for students to transfer from one division to another of the College without great hindrance when for one reason or another a change of objective is desirable. Thus, no applicant in his first year need feel that by committing himself to a particular branch of engineering education he has made an irrevocable decision.

After the second year, as the several curricula begin to diversify, transfer within the College of Engineering is somewhat more difficult and in a few instances may necessitate an additional term or more of study.

Applications for transfer should be made to the Director of the prospective school during the term preceding the one in which the student wishes to change his course, and students should realize that the earlier such transfers are made the fewer will be the resulting complications of curricular adjustment.

SPECIAL PROGRAMS OF STUDY

THE INDUSTRIAL COOPERATIVE PROGRAM

During the fourth term the regular curriculum students in electrical and mechanical engineering and in engineering physics who are in good standing may apply for admission to the Industrial Cooperative Program.

The Cooperative Program provides three work periods of term length (about 16 weeks each) in one of the following industries operating the plan with the University: American Electric Power Service Corporation, Air Reduction Company, Baldwin Piano Company, Cornell Aeronautical Laboratory, General Electric Company, International Business Machines Corporation, Philco Corporation, Procter and Gamble, and Raytheon Manufacturing Company.

By utilizing the three summer periods after the fourth term (normally vacation periods), Cooperative students are enabled to complete all the academic work regularly required for the Bachelor's degree and can graduate with their regular classes. The schedule is as follows after Term 4:

Period	*Term*	*Term*	*Term*
Summer	5	Industry	8
Fall	Industry	7	9
Spring	6	Industry	10

It is to be noted that the Cooperative student remains with his regular classmates during all terms on campus except the fifth and eighth, which he takes in the summer. The Cooperative Program therefore is not an accelerated program and involves a minimum of departure from the regular program.

Although the student is on the industry payroll during the work periods, the function of the plan is educational rather than to provide part-time employment. The work in industry is coordinated with the student's studies so far as practicable and provides an invaluable opportunity for him to direct his study interests on campus toward the realities of his future environment. Supervision is provided for each student, both from campus and industry, to ensure his obtaining optimum benefit from the Program. Many students have found this a profound influence on their objectives and on their progress both before and after graduation.

Applications for the Cooperative Program are accepted in the fourth term only. Applicants are subject to approval both by the College and by one of the cooperating industries. Admission to the plan involves no obligation on the part of either the student or the industry with regard to future employment.

COMBINED PROGRAMS IN LAW, BUSINESS AND PUBLIC ADMINISTRATION, AND CITY AND REGIONAL PLANNING

During the third and fourth years of the regular curriculum, students in good standing in some divisions of the College of Engineering may apply for admission to special programs which will permit the completion of requirements for both the appropriate Bachelor's degree in engineering and one of the advanced or graduate degrees in law, business and public administration, or city and regional planning, in one year less than the normal period.

Ordinarily such a combined program, leading to two degrees, would constitute an eight-year course of study in the case of law and seven years in the case of business and public administration or city and regional planning. By choosing as electives courses acceptable to the other schools or colleges and by being permitted to count certain other courses as meeting requirements in both areas, students will be able to acquire the two degrees in the shortened period.

Arrangements for one or more such combined programs of study are possible for selected students in chemical, civil, electrical, and metallurgical engineering. Applications will be accepted at any time prior to the fifth year, but, for maximum flexibility and ease of program planning, the choice should be made as early as possible. Applications must be approved by both participating schools or colleges in any instance.

UNDERGRADUATE STUDIES IN AERONAUTICAL ENGINEERING

Applicants interested in the field of aeronautical engineering should apply for admission to the Department of Engineering Physics, the School of Electrical Engineering, or the School of Mechanical Engineering. In the regular five-year programs of these schools they will obtain the fundamental scientific and humanistic courses that an aeronautical engineer must have; in addition, they may elect aeronautical engineering courses in the Graduate School of Aeronautical Engineering during their fourth and fifth years (provided that their scholastic records at that time are adequate). They can also carry out senior projects in the aeronautical field, under the direction of staff members of the School of Aeronautical Engineering. By planning their programs in this way, these students obtain an unusually sound and well-rounded aeronautical engineering education, combining the broad engineering training of Cornell's five-year undergraduate curricula with specialized aeronautical studies of the type usually reserved for graduate students.

Applicants should mention their interest in aeronautical engineering when they apply for admission. The Director of the Graduate School of

Aeronautical Engineering will assist them in planning their fourth and fifth-year programs so as to take greatest advantage of the offerings of that School.

NUCLEAR TECHNOLOGY

An elective program planned to prepare men for work in nuclear technology is available for qualified students in chemical, civil, electrical, mechanical, and metallurgical engineering and in engineering physics. Based on the premise that engineers will be the most productive in the nuclear power field if they are able to apply their particular field of engineering in combination with a sound knowledge of nuclear physics and related technical subjects, the program provides a series of coordinated elective courses in the fourth and fifth years and at the graduate level. The topics covered include atomic and nuclear physics, laboratory experiments in nuclear measurements and engineering, principles and design of nuclear reactors, advanced heat transfer and diffusion, reactor materials, radiation damage, fuel processing, waste disposal, etc. The courses, which may be classified into three groups—introductory, advanced, and supplementary—are listed below. Detailed descriptions can be found in the "Description of Courses" section of this Announcement.

Introductory: 8301 (or Physics 243), 8311, 8351, 3605 (or 3665 or 5505), 5760, 6872

Advanced: 8312, 8313, 8321, 8352

Supplementary: Various courses in chemistry, mathematics, physics, and in the several divisions of the College of Engineering.

The introductory group provides a relatively complete coverage of the entire field of nuclear engineering.

The student interested in the nuclear power field should consult with his adviser for assistance in planning a program of courses. It is advisable to make these plans in advance of the fourth year, which is the normal time to start the program. The student who is unable to elect the complete program may take only a portion, provided, however, that prerequisites for the desired courses are met.

Extensive laboratory facilities include a subcritical reactor. Construction of a training and research reactor and of a critical facility will start by early 1960. Many additional facilities are described in the sections devoted to the various schools and departments.

GRADUATE STUDIES

A graduate student holding a baccalaureate or equivalent degree from a college or university of recognized standing may pursue advanced work leading to a graduate degree in engineering. Such a

student may enter as a candidate either for the general degrees (M.S. or Ph.D.) or for the professional degrees (M.Ch.E., M.C.E., M.E.E., M.I.E., M.M.E., M.Met.E.).

The general degrees (M.S. and Ph.D.) are available in all the fields and subdivisions of the College of Engineering. They are administered by the Graduate School and require work in both major and minor fields of study, as well as the completion of a satisfactory thesis, usually involving individual and original research. A prospective graduate student interested in obtaining an M.S. or Ph.D. should consult the *Announcement of the Graduate School* for additional information concerning these degrees and should correspond with the professor supervising the particular field of engineering representing his major interest. Students who do not completely meet the entrance requirements for these degrees may be admitted as provisional candidates or without candidacy according to previous preparation, but they must in all cases hold a baccalaureate or equivalent degree.

Professional degrees at the Master's level are available in all the schools of the College and in the Departments of Industrial Engineering and Mechanics and Materials. These are degrees involving specific curricula and are administered by the Engineering Division of the Graduate School. In contrast to the general degrees, they do not require work in a minor field or the presentation of a thesis based upon research studies. Students who have completed four years of appropriate work in the College of Engineering at Cornell, or any student holding a baccalaureate degree in engineering or science deemed appropriate to the proposed study, may begin work leading to these professional degrees.

Because of the great diversity that exists in the practice of the different branches of engineering, the curricula of the several professional Masters' degrees differ in content. The prospective student should consult the more detailed descriptions of the curricula of the various schools elsewhere in this Announcement. These professional degrees should be considered to be at the five- and one-half to six-year level of university work, requiring from one to two years of additional study beyond a four-year baccalaureate degree. The required number of credit hours in each curriculum may be reduced by allowing credit for advanced work completed before entrance into the program. Professional experience substantially covering the same area as any part of the student's curriculum may, after investigation by the faculty, be given corresponding credit, provided that the credit hours earned in this way, plus the allowance for advanced work completed before entry into the program, do not exceed fifteen hours.

Information concerning graduate scholarships, fellowships, and assistantships can be obtained either from the Dean of the Graduate School or the Dean of the College of Engineering.

Prospective candidates for the degree of M.Aero.E. should apply directly to the Director of the Graduate School of Aeronautical Engineering.

THE ENGINEERING LIBRARY

The engineering library is in Carpenter Hall, a magnificent new building finished in 1957, and given to Cornell by Walter S. Carpenter, Jr., Cornell '10. Its inviting reading rooms and book stacks contain a basic and rapidly growing collection of books, periodicals, documents, reports, and pamphlets supporting all the branches of engineering taught in the schools and departments of the College. The resources of the library are housed in a pleasant atmosphere created by the attractive design of the building, the convenient arrangement of its facilities, and its handsome furnishings. In addition to the conventional facilities for reading and research, comfortable chairs for leisurely reading, individual study tables, and a typing and microtext reading room are provided. A staff of professional librarians furnishes reference, bibliographical, reserve, and circulation services.

A special feature of the library in Carpenter Hall is the Browsing Room. Furnished as a club, this handsome paneled room houses about 1500 selected books in the fields of the humanities and the social studies. It is designed to provide for students and faculty an inviting collection of cultural reading in an atmosphere of leisure, quiet, and dignity.

Allied and supporting literature in the basic sciences is to be found in the chemistry library, the physics library, and the mathematics library. Historical literature in all the sciences is located in the collections of the main University Library. The library resources of Cornell total more than 2,000,000 volumes.

COLLEGE REQUIREMENTS

Baccalaureate degrees are conferred on candidates who have fulfilled the following requirements:

1. The candidate must have been in residence and registered in the College of Engineering for the last two terms and must have satisfied the University requirements in military training and physical education and for the payment of tuition and fees.

2. He must have completed to the satisfaction of the faculty of the College of Engineering all the subjects and the elective hours prescribed in the course of study as outlined by that faculty.

3. A student who transfers to the College of Engineering, after having spent one or more terms in another college of Cornell University or elsewhere, must conform to the requirements of the class with which he graduates.

4. Each student in the first term of the freshman year in the College of Engineering must attend regularly the lectures in orientation for students in engineering.

The College of Engineering reserves the right to modify its curricula and specific courses of instruction, to alter the requirements for admission or for graduation, and to change the degrees to be awarded; such changes are applicable to either prospective or matriculated students at any time the College may determine.

UNIVERSITY REQUIREMENTS

MILITARY TRAINING

As a land-grant institution chartered under the Morrill Act of 1862, Cornell offers courses in military science which include all branches of the service (Army, Navy, Air Force, and Marines). Successful completion of such courses and receipt of a baccalaureate degree qualify a male student for a commission in the Regular or Reserve component of the appropriate service.

Participation in military training during the first four terms is mandatory for all physically qualified undergraduate men who are United States citizens. Satisfactory completion of the basic course in military science and tactics, air science, or naval science fulfills this requirement. (See also the *Announcement of the Independent Divisions and Departments.)*

For a student entering with advanced standing, the number of terms of military training required is to be reduced by the number of terms which he has satisfactorily completed (not necessarily including military science) in a college of recognized standing. Service in the armed forces may under certain conditions also satisfy the military training requirement.

Entering students who have had previous ROTC training in secondary or military schools are requested to obtain DA Form 131 (Student's Record—ROTC) from the institution previously attended and to present it to the appropriate military department during registration. (See also page 135 of this Announcement.)

PHYSICAL EDUCATION

All undergraduate students must complete four terms of work, three hours a week, in physical education. Ordinarily, this requirement must be fulfilled in the first two years of residence; postponements are to be allowed only by consent of the University Faculty Committee on Requirements for Graduation.

Exemption from this requirement may be made by the committee designated above, when it is recommended by the medical office or

when unusual conditions of age, residence, or outside responsibilities require it.

For students entering with advanced standing, the number of terms of physical education required is to be reduced by the number of terms which the student has satisfactorily completed (whether or not physical education was included in his program) in a college of recognized standing.

PAYMENTS TO THE UNIVERSITY

For information concerning tuition and other fees payable to the University, see the *Announcement of General Information.*

STUDENT PERSONNEL SERVICES

STUDENT PERSONNEL OFFICE

The admission of new students, the administration of scholarships in the College of Engineering, and the placement of graduates are activities of the College which are coordinated in the Student Personnel Office. The Personnel Office, in addition to other facilities, is also available at all times to students who wish to discuss any question relating to their life in the College.

STUDENT COUNSELING

In general, the counseling of students rests with the class advisers to whom the students are assigned primarily for assistance in planning and scheduling their academic work, but who will welcome students at any time to discuss other personal matters. In each school of the College, students are referred to the chairman of the scholarship committee when in financial need and to a placement adviser for assistance in vocational choice and postgraduate employment. Also, the students are free to consult with the dean, directors, department heads, and instructors, not only on matters pertinent to their education and future plans, but also on personal matters. In addition, the University's Dean of Men and Dean of Women and their staffs may be consulted by students regarding their nonacademic problems. Both Deans have offices in Edmund Ezra Day Hall.

HEALTH SERVICES AND MEDICAL CARE

The health services and medical care of Cornell students are centered in the University's Gannett Medical Clinic (out-patient department) and in the Cornell Infirmary (hospital). Students may consult a physician at the Clinic whenever need arises and receive treatment in cases that do not require hospitalization. If hospital care is indicated, the student is requested to enter the Infirmary. For details of the health and

medical services covered by the student's College and University General Fee, see the *Announcement of General Information.* On a voluntary basis, insurance is available to supplement the services provided by the General Fee; information about such insurance may be obtained at the Gannett Medical Clinic.

ASSISTANCE TO FOREIGN STUDENTS

The University has a Foreign Student Office headed by a Director whose duty is to look after the welfare of all students from other countries. He may be consulted on personal problems, social questions, or any other matter in which he may be helpful. His office is in Edmund Ezra Day Hall. It is suggested that all foreign students write him before coming to Ithaca or call on him immediately upon arrival.

FRESHMAN ORIENTATION

A series of orientation lectures is given to students in the fall term of the freshman year in the College of Engineering. Their primary purpose is to acquaint the student with the scope of each of the major fields of engineering and with the opportunities and the responsibilities of members of the engineering professions.

SCHOLARSHIPS, PRIZES, AND FINANCIAL AID

SCHOLARSHIPS FOR FRESHMEN

Information about scholarships open to entering students in *any* undergraduate division of the University and application blanks may be obtained from the Scholarship Secretary, Office of Admissions, Edmund Ezra Day Hall. The scholarships described below are available *only* to students entering the College of Engineering.

AMERICAN SOCIETY FOR METALS SCHOLARSHIP. . . Established by the National Society for Metals Foundation for education and research. Normally awarded to an entering freshman or upperclassman in metallurgical engineering. Tenure one year. Award, $500.

CHARLES R. ARMINGTON SCHOLARSHIPS IN ENGINEERING . . . Gift of Mr. and Mrs. R. Q. Armington, in memory of their son who was a student in the School of Mechanical Engineering at the time of his death in 1956. Open to men students in any branch of engineering. One scholarship annually with annual stipend up to $2000. Tenure, not limited. Selection based on balance of academic and extracurricular interests with outstanding personal characteristics.

JOHN HENRY BARR SCHOLARSHIP. . . Gift of Mrs. Mabel R. Barr, for a deserving student to be chosen by the University from recom-

mendations of the Cornell Club of the Lehigh Valley. Annual award, up to $2000. Tenure not limited.

LAWRENCE D. BELL MEMORIAL SCHOLARSHIP. . . Established by the Bell Foundation, Inc. Open to men or women entering any branch of engineering. One or more awards with annual stipend up to $1250. Tenure, not limited. Selection based on scholarship, leadership qualities, and financial need.

EDWARD P. BURRELL SCHOLARSHIPS. . . Gift under the will of Katherine W. Burrell, in memory of her husband. Open to men and women entering any division of the College of Engineering. Award, up to $800 for freshmen year only. Need is an important factor in selecting the winners.

WILLIS H. CARRIER SCHOLARSHIP. . . Established by the Carrier Foundation, Inc. Open to entering students in the School of Mechanical Engineering. Annual award, $750. Tenure, not limited. Selection is based on scholastic promise and financial need.

GENERAL MOTORS COLLEGE SCHOLARSHIP. . . Established 1957 by the General Motors Corporation. Available to men or women who are citizens of the United States entering the College of Engineering. One scholarship annually with stipend of from $200 to $2000 depending upon need. Tenure, unlimited. Selection based upon outstanding academic promise, general character, and financial need.

INLAND STEEL FOUNDATION SCHOLARSHIPS. . . Established by the Inland Steel Foundation. Annual award, $1500. Tenure, not limited. Selection is based on scholastic attainment, personal characteristics, and financial need. Summer employment may be offered to recipient by the Inland Steel Company. (Not available in 1960–1961.)

MARTIN J. INSULL SCHOLARSHIP. . . Gift of his wife, Mrs. Virginia Insull. Open to men entering the College of Engineering. Annual award, $1500. Tenure, not limited. Further provisions as for the McMullen Regional Scholarships (see below), except that financial need is an essential criterion.

LOCKHEED NATIONAL ENGINEERING SCHOLARSHIP. . . Established by the Lockheed Leadership Fund. Open to entering students in the College of Engineering. Annual award, tuition and fees plus $500. Tenure, unlimited. One award each year to a student who is in a field of engineering applicable to the aircraft industry and whose total personal qualities can be expected upon graduation to offer a significant contribution to the aircraft industry.

JOHN McMULLEN REGIONAL SCHOLARSHIPS. . . Gift under the will of John McMullen. Open to men entering any division of the

College of Engineering. Annual award, up to $1425. Tenure, not limited. Fifty or more scholarships awarded annually. Applicants will be selected on the basis of high scholastic achievement and other indications of qualities likely to produce leadership in engineering. Although financial need is not a factor in selecting the winners, full consideration will be given to need in fixing stipends.

OWENS-ILLINOIS SCHOLARSHIP. . . Established by Owens-Illinois. Open to men. Annual award, tuition and fees plus $125 for books and supplies in the freshman year and $100 annually thereafter. Tenure, not limited. Selection will be based on scholastic achievement, personality, and financial need. Summer employment may be offered by Owens-Illinois.

PROCTER AND GAMBLE SCHOLARSHIPS. . . Established by the Procter and Gamble Company. Open to men or women entering the College of Engineering. Annual award, $1540, covering tuition, fees, books, and supplies. Tenure, unlimited. Selection based on academic achievement, character, and financial need.

ALFRED P. SLOAN NATIONAL SCHOLARSHIPS. . . Established by the Alfred P. Sloan Foundation. Open to men entering any division of the College of Engineering. Annual award varies from a prize scholarship of $200 to as much as $2000, depending upon financial need. Tenure, not limited. Nine scholarships awarded annually. Applicants will be selected on the basis of high character, sound personality, leadership potential, and professional promise.

SOLVAY SCHOLARSHIP. . . Established by the Solvay Process Division of Allied Chemical and Dye Corporation. Open to an entering student or upperclassman in chemical engineering. Award, $1000. Tenure, one year. Selection will be based upon scholarship, personality, and financial need. (Not available in 1959–1960.)

JESSEL STUART WHYTE SCHOLARSHIP. . . Gift of Mrs. Anna Jessel Whyte in memory of her son. Open to entering students in the Sibley School of Mechanical Engineering. Annual award, $1000. Tenure, not limited. Preference will be given to residents of Illinois, Iowa, Michigan, Minnesota, and Wisconsin. Further provisions as for McMullen Regional Scholarships.

SCHOLARSHIPS AND GRANTS-IN-AID FOR UPPERCLASSMEN

Students in their sophomore year and beyond may apply for financial assistance through the Office of Financial Aids, Edmund Ezra Day Hall.

Awards are of two general types: (1) those for which the principal qualification is financial need, and (2) those for which outstanding scho-

lastic achievement is the chief criterion. In the first category are scholarships which are essentially grants-in-aid and which have variable stipends up to full tuition in any year. Eligibility extends to any student not on scholastic probation.

The second category of awards, based on high scholastic and other attainments, consists of (1) a limited number of scholarships sponsored by industrial companies, mostly for students in their last two years of study, and (2) such vacancies as may occur in scholarships of this type usually awarded to entering students and subject to renewal.

Below are the scholarships sponsored by industrial companies and foundations.

ALLEGHENY LUDLUM SCHOLARSHIP. . . Established by the Allegheny Ludlum Steel Corporation. Award, $500. Tenure, three years. Awarded annually to a student in chemical or metallurgical engineering, normally to a student in metallurgical engineering, with primary consideration for academic record, promise of ability, and success in his field of study. Need is a secondary factor.

THE AMERICAN BRAKE SHOE SCHOLARSHIP. . . Established by the American Brake Shoe Company. Open to juniors and seniors or fifth year students in mechanical, chemical, or metallurgical engineering. Three scholarships of $1025 each to be awarded annually. Renewable to students in good standing. (No award in 1959–1960.)

CHARLES R. ARMINGTON PRIZE SCHOLARSHIP IN ENGINEERING. . . Gift of Mr. and Mrs. R. Q. Armington, in memory of their son who was a student in the School of Mechanical Engineering at the time of his death in 1956. One scholarship annually to a student entering his fourth year in any branch of engineering with annual stipend of $500 or more depending upon need. Tenure, two years. Recipients will be students who in their first three years of college have demonstrated outstanding qualities of personality, notably sportsmanship of a high order.

ASARCO SCHOLARSHIP. . . Established by the American Smelting and Refining Company. Open to a fourth or fifth year student in chemical, mechanical, or metallurgical engineering. Annual award, $500. Selection based on scholastic achievement and leadership potential.

BENDIX AVIATION HONORS SCHOLARSHIP IN SCIENCE AND ENGINEERING. . . Established in 1957 by the Bendix Aviation Corporation. Open to a senior who is outstanding in scholarship, ability, character, and promise, studying in a field of interest to the Corporation, and who is a U.S. citizen. Annual award, $1,425.

BLONDER-TONGUE FOUNDATION AWARD. . . Established in 1957 by the Blonder-Tongue Foundation. A prize scholarship of $250

to be presented annually to a student entering his fifth year in recognition of high scholastic attainment in the demonstration of outstanding potential in the fields of radio and television (electronics). Financial need is not a factor.

CHEMSTRAND SCHOLARSHIP...Established in 1958 by the Chemstrand Corporation. Open to a senior in chemical engineering who is a superior student and a U.S. citizen. Annual award, $500.

DOW CHEMICAL COMPANY SCHOLARSHIPS...Established by the Dow Chemical Company. Award, $1000. One scholarship to be awarded annually and renewable for the fifth year to a student in chemical engineering. One other scholarship, with a tenure of one year and a stipend of $500, will be awarded annually to an upperclassman in metallurgical engineering.

DRAVO CORPORATION SCHOLARSHIPS...Established by the Dravo Corporation. Open to fourth year students in civil, electrical, or mechanical engineering. One new award of $1000 annually; may be renewed for fifth year. Selections based on scholastic ability, need, and personal characteristics.

FOUNDRY EDUCATIONAL FOUNDATION SCHOLARSHIPS... Open to all students (except freshmen) in metallurgical and mechanical engineering who are interested in preparing themselves for professional engineering work in the foundry industries. Annual award, up to $600. Tenure, one or more years. Awarded on the basis of leadership, financial need, scholastic standing, and interest in foundry work.

I-T-E FOUNDATION SCHOLARSHIP AWARD...Established in memory of the founders of the BullDog Electric Products Company. Open to third year students in the School of Electrical Engineering who are interested in the control and distribution of electric energy. One scholarship annually in the amount of $700, subject to renewal.

MONSANTO SCHOLARSHIP...Established by the Monsanto Chemical Company. Open to seniors in the School of Mechanical Engineering and fifth year students in the School of Chemical and Metallurgical Engineering. Award based upon academic standing, interest in chemistry, and probability of success. Financial need not considered. Annual award, $700.

THE SCOTT AWARD AT CORNELL...Established by the Scott Paper Company. One scholarship awarded annually to an outstanding fourth year student in mechanical engineering who intends to follow an industrial career. Tenure, two years. Award, $500 to $1000, depending upon need. The recipient must have demonstrated those high qualities of intellect, personality, and physical vigor associated with the Rhodes Scholars.

THE TRANE COMPANY SCHOLARSHIP. . . Established by the Trane Company of La Crosse, Wisconsin. Open to seniors in mechanical engineering with special interest in air conditioning, refrigeration, or heat transfer. Annual award, $1000. Selection to be based on scholastic attainment, need, and leadership potential.

WESTERN ELECTRIC SCHOLARSHIPS. . . Established by the Western Electric Company. Open to students in any division of the College of Engineering. Three scholarships with annual award up to $800 to be applied against the cost of tuition, fees, and books. Tenure, one year; may be renewed. Selection based upon need and ability in fields of study related to the Company's operations.

WESTINGHOUSE AIR ARM DIVISION SCHOLARSHIP. . . Established in 1956 by the Westinghouse Electric Corporation. Award, $500. One scholarship annually to a third year student in electrical or mechanical engineering or engineering physics standing in the top third of his class. Tenure, three years.

WYMAN-GORDON SCHOLARSHIP. . . Established by the Wyman-Gordon Company. One award of $1425 annually to a fifth year student in mechanical or metallurgical engineering.

LOANS

The University maintains substantial loan funds from which students may borrow after they have been in residence for two terms and provided they are in good standing. Loans bear no interest while the student is in the University, and usually not more than 4 per cent annually after he leaves until repayment is made. Applications for loans should be made through the Office of Financial Aids, Edmund Ezra Day Hall.

PART-TIME EMPLOYMENT

Students wishing to earn a part of their living expenses by working on or near the campus during the school year should apply in advance of registration to the Office of Financial Aids, Edmund Ezra Day Hall. Freshmen are advised to meet their first year expenses by other means if possible, until by experience they have learned how much time they will have available to devote to such employment.

PRIZES

Cornell University has a considerable number of funds given for the endowment of prizes to be awarded annually. Some of these prizes are open to competition by any students in the University. The publication, *Prize Competitions*, describing the prizes and the nature of the competi-

tions, will be mailed on request addressed to Cornell University Announcements, Edmund Ezra Day Hall. Prizes open to competition particularly by students of the College of Engineering are:

THE AMERICAN SOCIETY OF TESTING MATERIALS PRIZES, consisting of six one-year memberships in the Society, are awarded to students in the College of Engineering for the highest scholastic average in materials.

THE AMERICAN INSTITUTE OF CHEMICAL ENGINEERS PRIZE is a badge awarded by the School of Chemical Engineering to a junior in chemical engineering for the best scholastic record at the end of the fourth term.

THE CHARLES LEE CRANDALL PRIZES, founded in 1916 by alumni of the School of Civil Engineering. The prizes of $75, $50, $35, and $20 are awarded each year by a committee appointed by the Director of the School of Civil Engineering for the best papers written by seniors or juniors in that School on suitable subjects, provided that both the substance and the written form of the papers submitted show real merit. The prizes were established to encourage original research, to stimulate interest in matters of public concern, and to inspire in the students an appreciation of the opportunities which the profession of civil engineering offers them to serve their fellow men as intelligent and public-spirited citizens. Papers must be submitted to the Director of the School of Civil Engineering on or before March 15 of each year.

THE FUERTES MEDALS, established by the late Professor E. A. Fuertes. The endowment provides for two gold medals. One is awarded annually by the faculty to that student of the School of Civil Engineering who is found at the end of the first term of his senior year to have maintained the highest degree of scholarship in the subjects of this course, provided he has been in attendance at the University for at least two years. The other is awarded annually by the faculty to a graduate of the School of Civil Engineering or the recipient of a graduate degree with major in civil engineering who has written a meritorious paper upon some engineering subject tending to advance the scientific or practical interests of the profession of the civil engineer. It is desired that papers be presented on or before April 15. If a paper is presented in printed form, it will not be received if it has been printed earlier than the next preceding April 15. Neither medal is awarded unless it appears to the faculty of the School of Civil Engineering that there is a candidate of sufficient merit to entitle him to such distinction.

THE FUERTES MEMORIAL PRIZE IN PUBLIC SPEAKING, founded by the late Charles H. Baker, a graduate of the School of Civil

Engineering of the class of 1886. Three prizes, one of $100, one of $40, and one of $20, are offered annually to all students of the Colleges of Engineering and Architecture who are in the fifth term or beyond, for proficiency in public speaking.

THE HAMILTON AWARD. . . A suitably engraved Hamilton watch and letter of commendation is awarded annually to the senior in engineering who has most successfully combined proficiency in his major field of study with achievements, either academic, extracurricular, or a combination of both, in the social sciences and humanities.

THE INSTITUTE OF AERONAUTICAL SCIENCES PRIZE. . . The "Student Branch Scholastic Award" of the Institute of Aeronautical Sciences is presented annually to the M.Aero.E. candidate who attains the best scholastic record for that academic year. The award consists of a certificate and a two-year free technical membership in the Institute.

SIBLEY PRIZES. . . Under a gift of Hiram Sibley, made in 1884, the sum of $100 is awarded annually in several prizes to fifth year students in mechanical engineering and electrical engineering, equally distributed, who have received the highest average in the preceding four years.

THE SILENT HOIST AND CRANE COMPANY MATERIALS HANDLING PRIZES of $125 and $75, established in 1950 by the Wunsch Foundation, are awarded each year for the best original papers on the subject of materials handling. This contest is open to undergraduate and graduate students of the College of Engineering.

THE J. G. WHITE PRIZES IN SPANISH. . . Through the generosity of James Gilbert White (Ph.D., Cornell, '85), three prizes, established in 1914, each of the value of $100, are offered annually. One of the three, which is awarded to an English-speaking student for proficiency in Spanish, is open to members of the junior and senior classes in the College of Engineering who are candidates for their first degree. No candidate is eligible unless he has completed successfully two terms of work in Spanish at Cornell University.

GRADUATE SCHOLARSHIPS AND FELLOWSHIPS

Graduate students whose major subjects are in the various branches of engineering and who wish to be candidates for scholarship or fellowship aid should consult the *Announcement of the Graduate School* and make application to the Dean of the Graduate School. Those who are candidates for the degree of M.Aero.E. should apply to the Director of the Graduate School of Aeronautical Engineering.

STUDENT HONORS AND ACTIVITIES

DEAN'S HONOR LIST

Students of the College of Engineering whose weighted average in their studies is 85 per cent or better are included annually in an Honor List compiled for the Dean. The honor students comprise approximately the highest tenth of all the students enrolled in the College.

STUDENT ACTIVITIES

Students of the College of Engineering find many opportunities for engaging in wholesome activities outside their regular duties, and even outside the College, in company with other members of the University community. Within the College some find congenial occupation in helping to carry on the student branches of the national engineering societies, or in membership in national or local honor societies, which include Tau Beta Pi, Phi Kappa Phi, Sigma Xi, Pi Tau Sigma, Chi Epsilon, Rod and Bob, Pyramid, Atmos, Kappa Tau Chi, and Eta Kappa Nu. In the University at large there are student activities of all sorts—musical, dramatic, journalistic, social, and athletic.

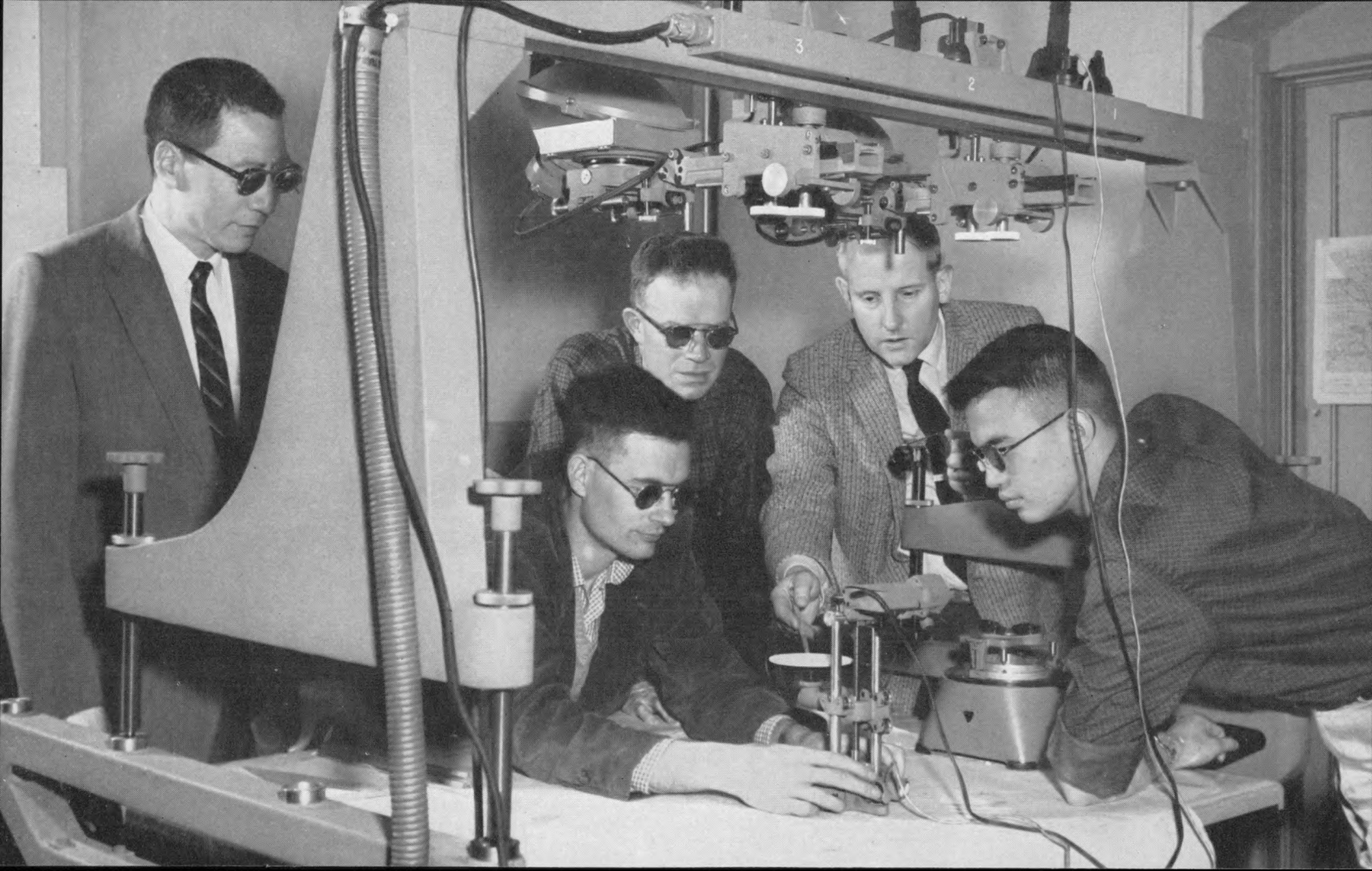
THE CORNELL ENGINEER, a technical journal published monthly throughout the academic year, is managed and edited by undergraduates in the College of Engineering.

ENGINEERING SOCIETIES

The College of Engineering is closely associated with the local sections of the American Society of Civil Engineers, American Society of Mechanical Engineers, American Institute of Electrical Engineers, Society of Automotive Engineers, and Institute of Radio Engineers, many of the meetings of which are held on the campus and are participated in by the members of the College. The College also maintains active student branches of these national societies as well as of the American Institute of Chemical Engineers and the Institute of Aeronautical Sciences. The Cornell Metallurgical Society was formed in 1949 and is an affiliate of the American Institute of Mining and Metallurgical Engineers.

A student Branch of the American Nuclear Society was founded early in 1959.

The meetings of such societies afford opportunities for addresses by engineers of eminence, for the presentation of papers by students, for discussion, or for contests in public speaking on engineering subjects. The School of Mechanical Engineering gives elective credit hours for activity in the student branches of the A.S.M.E.



SCHOOL OF CIVIL ENGINEERING

THE PROFESSION of civil engineering pertains to the design, construction, and maintenance of major buildings, bridges, dams, airports, thruways, railways, canals, tunnels, pipelines, etc. Advanced civil engineering includes such work as the planning and administration of systems of transportation, flood control, city management, soil and water conservation, resource development, and sanitation.

About 20 per cent of the graduates from civil engineering serve the public as federal, state, or city employees. The other 80 per cent are widely distributed and are found in such employment as private consulting, construction management, and engineering design for engineering organizations. Future opportunities should be excellent because of expanding needs for civil engineers and the relatively small number of high school students who have elected this field as a profession since World War II.

EQUIPMENT

A new civil engineering building, to be occupied in the fall of 1959, was given to Cornell by Spencer T. Olin of the class of '21, and has been named Hollister Hall. This building provides offices for faculty and graduate students, project rooms for fifth year students, lecture rooms, seminar-computation rooms, design rooms, and an auditorium with a capacity of 220. A lounge with an adjacent kitchen will be available for social events of the faculty, students, and alumni. Instruction and research laboratories are provided for transportation engineering, sanitary engineering, photogrammetry and surveying, soil mechanics, structural models, and air photo interpretation. The hydraulics department will continue to use the laboratory facilities at Beebe Lake, and a new hydraulic instruction laboratory has been added in the new building. Provision has also been made in the new building for the machine shop which produces special equipment for research and instruction. All of these laboratories are modern and well equipped for instruction and research.

Additional facilities for the structures department, including equipment for three-dimensional testing of specimens or large structural elements made of any of the building materials, are provided in Thurston Hall, the mechanics and materials building adjacent to the new civil engineering building.

By using a stereo plotting instrument to project aerial photographs with colored light, civil engineers make topographical maps rapidly and conveniently.

The surveying equipment is composed largely of instruments recently purchased, including American and foreign designs of the most modern type.

COURSES OF STUDY

The courses of study offered by the School of Civil Engineering lead to the degree of Bachelor of Civil Engineering and are planned to provide fundamental instruction for the practice of the profession. To meet this objective, the major portion of the curriculum is definitely prescribed, both as to technical content and humanistic studies. Each student, however, is permitted to choose elective courses in various fields which can be planned to intensify his training in a specific area or to increase his general background.

CURRICULUM (B.C.E.)

			CONTACT HOURS	
		CREDIT HOURS	LEC. REC.	LAB. COMP.
TERM 1	Mathematics 161, Analytic Geometry and Calculus	3	3	0
	Physics 121, Introductory Analytical Physics I	3	3	2½
	Chemistry 105, General Inorganic Chemistry	3	2	3
	English 111, Introductory Course	3	3	0
	Engineering 2001, Drawing	3	0	7½
	Total	15		
TERM 2	Mathematics 162, Analytic Geometry and Calculus	3	3	0
	Physics 122, Introductory Analytical Physics II	3	3	2½
	Chemistry 106, General Inorganic Chemistry	3	2	3
	English 112, Introductory Course	3	3	0
	Engineering 2002, Drawing	3	0	7½
	Engineering 2111, Elementary Surveying	2	0	5
	Total	17		

In addition to these courses, all freshmen must satisfy the University's requirements in military training and physical education.

TERM 3	Mathematics 163, Analytic Geometry and Calculus	3	3	0
	Physics 123 or 125 or 127, Introductory Analytical Physics III	3	3	2½
	Chemistry 301, Organic Chemistry	2	2	0
	Geology 113, Engineering Geology (or Economics 103)	3	2	5
	Engineering 2113, Route and Aerial Surveying	3	1	5
	Engineering 1151, Mechanics-Statics	3	3	0
	Total	17		

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 4	Physics 124 or 126 or 128, Introductory Analytical Physics IV	3	3	2½
	Chemistry 402, Physical Chemistry	2	2	0
	Economics 103, Modern Economic Society (or Geology 113)	3	3	0
	Engineering 2112, Advanced Surveying	3	2	2½
	Engineering 1145, Applied Mathematics	3	3	0
	Engineering 1153, Strength of Materials	3	3	2½
	Total	17		

In addition to these courses, all sophomores must satisfy the University's requirements in military training and physical education.

	Engineering 2214, Summer Survey Camp	5	0	0
TERM 5	Engineering 1134, Strength of Materials	3	3	0
	Engineering 1152, Mechanics-Dynamics	3	3	0
	Engineering 2701, Elementary Structural Analysis	3	2	2½
	Engineering 2501, Microbiology in Engineering (or 1241)	3	2	2½
	Engineering 3630, Engineering Thermodynamics	3	3	0
	Socio-Economic Elective (or Speech 201)	3	3	0
	Total	18		
TERM 6	Engineering 4931, Electrical Engineering	3	2	2½
	Engineering 2301, Fluid Mechanics	3	3	0
	Engineering 3642, Heat Power II	2	2	0
	Engineering 2702, Elements of Metal and Timber Structures	3	0	7½
	Engineering 1241, Materials (or 2501)	3	2	2½
	Public Speaking 201 (or Socio-Economic Elective)	3	3	0
	Engineering 2602, Transportation (or 2901)	3	3	0
	Total	20		
TERM 7	History 165, Science in Western Civilization	3	3	0
	Engineering 4932, Electrical Engineering	3	2	2½
	Engineering 2302, Applied Hydraulics and Hydrology (or 2502)	3	2	2½
	Engineering 2704, Statically Indeterminate Structures (or 2903)	3	3	0
	Engineering 2901, Construction Methods (or 2602)	3	3	0
	Engineering 2725, Soil Mechanics (or 2715)	3	2	2½
	Total	18		

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 8	History 166, Science in Western Civilization	3	3	0
	Engineering 2412, Hydraulic Engineering (or 2503)	3	3	0
	Engineering 2715, Reinforced Concrete Design (or 2725)	3	0	6
	Engineering 2903, Economics of Engineering (or 2704)	3	3	0
	Engineering 2502, Water Supply & Sewerage Systems (or 2302)	3	2	2½
	Engineering 2610, Highway Engineering (or 1212)	3	2	2½
	Total	18		
TERM 9	Engineering 2902, Engineering Law (or 2904)...	3	3	0
	Engineering 2503, Water and Waste Treatment (or 2412)	3	2	2½
	Engineering 3231, Accounting (or ILR 293)	3	2	2½
	Engineering 1212, Materials Laboratory (or 2610)	3	1	5
	Engineering 2720, Foundations	3	2	2½
	Elective (Free)	3		
	Total	18		
TERM 10	Engineering 2904, Public Administration (or 2902)	3	3	0
	Industrial and Labor Relations 293, Survey of Industrial and Labor Relations (or 3231)	3	3	0
	Engineering 2713, Structural Design	3	0	6
	Electives (Free)	9		
	Total	18		

Grand total for ten terms: 181 credit hours including summer survey camp, but not including military training or physical education.

COMBINED PROGRAMS

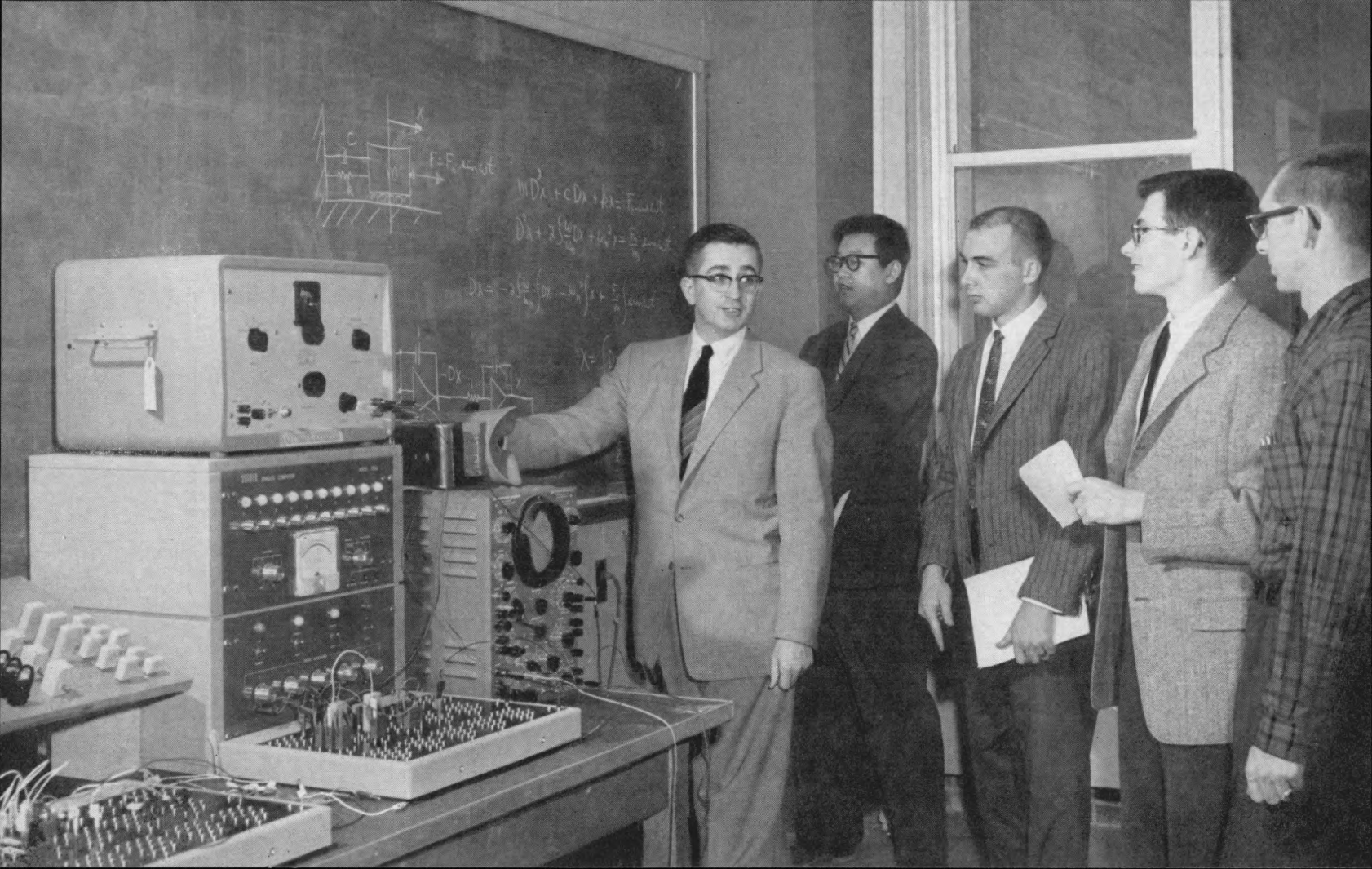
Combined Programs with Law (LL.B.), Business and Public Administration (M.B.A. and M.P.A.), and City and Regional Planning (M.R.P.) are available to selected students in civil engineering. By careful planning the student may complete the requirements for the B.C.E. degree in the regular period of five years, and for the second degree in one year less than normally required. Admission to these programs requires approval of the two schools involved, and double registration in the fifth year. Students interested in any of these programs should consult their advisers as early as practicable for detailed information.

SPECIAL GRADUATE PROGRAM

Qualified students may, by special permission, follow a program which will permit them to obtain the M.C.E. degree in less than one

extra year. To meet the requirements for the M.C.E. degree, a minimum of 45 semester hours of approved advanced courses must be satisfactorily completed.

Students will be accepted into the program at the end of the fourth year, but, for maximum flexibility and ease of scheduling, the decision to follow this program should be made as early as possible.



SIBLEY SCHOOL OF MECHANICAL ENGINEERING

EQUIPMENT

THE SIBLEY School of Mechanical Engineering, named in recognition of Hiram Sibley, an early business associate of Ezra Cornell, is housed primarily in Upson Hall. This magnificent building is the gift of Maxwell M. Upson, Cornell '99, and was completed in 1958 as part of the new engineering quadrangle at the south end of the campus. Adjacent to Upson Hall is Kimball Hall, which contains all the equipment used by the School for instruction in materials processing. Excellent engineering library facilities are provided in Carpenter Hall, completed in 1957.

Upson Hall has been designed to provide the finest laboratory and classroom facilities. These laboratories include the machine design laboratory, for instruction and research in photoelasticity, balancing vibration, stress, lubrication, and wear of machines and machine members; the steam laboratory, for instruction and research involving steam power, including a small-scale power plant consisting of the boiler, turbogenerators, control panels, and auxiliary equipment; the internal combustion engine laboratory with spark ignition and diesel engines, as well as CFR engines for fuel research; a turbomachinery laboratory for gas turbines; air conditioning and refrigeration laboratory for work in this field; a solar energy laboratory; methods engineering laboratory, for motion and time study and work measurement; the constant temperature room; the heat transfer and flow measurement laboratories; a group of laboratories for specialized research and student project research. All these laboratories are supported by a well equipped machine shop, staffed with qualified personnel for maintenance and the making of specialized research equipment. In Kimball Hall, in addition to a basic machine shop, there are a production machine tools laboratory and a measurement laboratory, including a constant temperature room for precise measurements.

Other laboratories in the College of Engineering that play an important role in the training of mechanical engineers include the materials testing laboratory, heat treatment laboratory, and the metallography laboratory for the determination of the physical properties of engineer-

A machine design class studies the results of electronic computer simulations of mechanical vibration and automatic control problems.

ing materials under various conditions. These laboratories are in Thurston Hall, which adjoins Kimball Hall.

OUTLINE OF THE INSTRUCTION

The object of the instruction in this School is to lay a broad and substantial foundation of general and technical knowledge, and to provide as much training in engineering practice in mechanical engineering and engineering administration as can well be imparted in a school.

Students of mechanical engineering are instructed primarily in the utilization of nature's sources of energy and materials for the benefit of mankind, through the development and application of prime movers, machinery, and processes of manufacture; thus, they have to do mainly with things dynamic. The province of the mechanical engineer includes the design, construction, operation, and testing of steam engines, steam turbines, steam generating apparatus, and power plant auxiliaries, internal combustion engines, hydraulic machines, pumping engines, railway equipment, compressed-air machines, ice making and refrigerating machinery, equipment for heating and ventilating and air conditioning, machine tools, mill equipment, and transmission machinery. The work of the mechanical engineer further includes the planning of power plants and factories, the selection and installation of their equipment, the development of systems of operation and manufacturing processes, and the organization and administration of plants and industries. In addition, the mechanical engineer may engage in scientific research in the innumerable branches of his field.

The general plan of the curriculum is to give a thorough training in mathematics and the basic sciences of physics and chemistry leading to the fundamental engineering sciences and technological courses. Parallel with this training are a group of courses in the social sciences and liberal fields to develop a better understanding of the social, political, and economic world in which the engineer must assume responsibility for leadership. The outline of the course of study shows how the training is integrated as well as the depth and scope of the subject matter to give the young engineer a sound foundation for his future professional growth.

Students who show proficiency in the first term of the introductory course in English may be permitted, with the consent of the Department of English, to substitute other courses in English or English literature in the second term.

PROJECT AND ELECTIVES

During the last three years, provision is made for the choice of elective courses and a senior project in the student's major field of study. His project may be an individual one or a group project in a technical,

managerial, or related field for the purpose of applying to one or more basic problems the fundamental concepts he has been taught in the preceding years and for the purpose of developing the ability to do work of an original nature.

The project may be in any one of many branches, such as management, industrial engineering, thermal engineering, internal combustion engines, heat engineering, heating, ventilating and air conditioning, refrigeration engineering, automotive engineering, aeronautical engineering, mechanical design, experimental stress analysis, design development, advanced mechanics and strength of materials, engineering materials, experimental engineering, materials processing, tool engineering, welding design, structural engineering, physics, nuclear engineering, electrical engineering, and other fields related to mechanical engineering.

The 35 hours of electives in the curriculum provide an opportunity for the student to select a wide variety of courses offered in the University, depending upon his interests and objectives. To ensure a reasonable breadth of training in fields other than engineering, beyond those courses already specified, the student must elect twelve credit hours of work from the fields of English, government, history, languages, philosophy, psychology, economics, sociology and anthropology, speech and drama, literature, music, fine arts, or the classics. To acquire some depth of training, it is strongly urged that a student take at least six credit hours of work in a given field.

A minimum of eleven credit hours of electives must be in approved courses in the College of Engineering. Usually these courses will be related to the student's project, but he does have the opportunity to pursue engineering specialties of great interest to him.

INDUSTRIAL AND ENGINEERING ADMINISTRATION

The training of engineers for the field of production engineering or industrial engineering has been an integral part of the Sibley School of Mechanical Engineering for the past fifty years. The increasing scientific developments underlying the operation of works and plants in many industries have put additional emphasis on the need for a sound background in such areas as materials, design, statistical procedures, materials processing, gaging and inspection, methods engineering, cost accounting and production engineering including product analysis, plant layout, engineering economy, and production control, all of which are required in the curriculum.

The emphasis is on the engineering aspects, with due regard for the importance of the human and personnel factors involved in successfully organizing and managing an industrial enterprise.

Modern managerial decisions involve the integration of many com-

plex variables. Problems of utilization of machines, men, and materials must be given careful consideration to obtain a decision economically sound from an over-all point of view. To cope with these problems and to give the student a solid foundation for eventual control and direction of these efforts, special programs of study have evolved at Cornell.

The student interested in this field can select suitable electives to further his training in such areas as psychology, industrial marketing and research, advanced statistics for quality control and analysis, personnel management, industrial organization, advanced methods engineering, production control, and operations research, or additional work in economics or in standard costs and control.

The existence of a School of Industrial and Labor Relations, a College of Arts and Sciences, and other divisions of the University on the same campus as the College of Engineering makes possible combinations of elective courses that are available at few other institutions in the country.

A student interested in industrial engineering will find a unique and comprehensive group of courses, all within the framework of a strong curriculum leading to the B.M.E. degree, available to him. A special booklet describing the program in more detail is available on request from the Department of Industrial and Engineering Administration, Upson Hall.

INDUSTRIAL COOPERATIVE PROGRAM

The School participates in the Engineering Industrial Cooperative Program providing periods of industrial experience interspersed among regular terms of study. The Program is described on page 13.

PROFESSIONAL MASTERS' DEGREES: M.M.E. AND M.I.E.

In addition to the graduate programs available to engineers in the Graduate School, leading to the M.S. and Ph.D. degrees, the College of Engineering has instituted a graduate program leading to professional Masters' degrees. Among the degrees offered are the Master of Mechanical Engineering (M.M.E.) and the Master of Industrial Engineering (M.I.E.).

Programs leading to both professional degrees are course programs providing advanced training in specified areas. To receive either degree, a student must complete 45 credit hours of work at an advanced level. This is the equivalent of three semesters of work over and above that usually required in a regular four-year program leading to a Bachelor's degree in engineering. By the proper choice of electives, candidates for the five-year B.M.E. degree at Cornell may complete the requirements for either the M.M.E. or M.I.E. in one additional semes-

ter. Thus, both the B.M.E. and a Master's degree could be earned in five and one-half years by a specially qualified student.

Specialized programs for an M.M.E. degree in the area of machine design are available in the fields of analysis and development, automatic machinery, and power machinery; in the area of thermal engineering, in the fields of combustion engines, heat transfer and fluid dynamics, nuclear and thermal power, and refrigeration and air conditioning.

Specialized programs for the M.I.E. degree are available in the areas of manufacturing engineering, methods engineering, cost control, industrial statistics, and operations research.

For further information concerning the programs for professional Masters' degrees, see the *Announcement of the Graduate School,* and the brochures entitled *Graduate Programs in Industrial Engineering* and *Graduate Programs in Mechanical Engineering.*

EMPLOYMENT AFTER GRADUATION

Graduates in mechanical engineering find employment in the design, construction, testing, and operation of prime movers and other machinery, and of complete plants in their own related fields, and in sales engineering and industrial research and development. They serve also as planners of new projects and processes, and as aeronautical engineers, air-conditioning engineers, industrial engineers, power-plant engineers, refrigeration engineers, research engineers, and teachers of engineering —to mention only a few of the many special fields open to them. With the instruction in liberal subjects and those related to administration and management coupled with the technical training, they have special qualifications to develop into leaders in their chosen fields.

SCHOLASTIC REQUIREMENTS

A student in the School of Mechanical Engineering who fails in any term to earn a passing grade in 15 hours, with a grade of 70 or better in 11 hours, may be placed on probation. If he fails in any term to pass 12 hours he may be dropped from the School.

CURRICULUM (B.M.E.)

			CONTACT HOURS	
		CREDIT HOURS	LEC. REC.	LAB. COMP.
TERM 1	Mathematics 161, Analytic Geometry and Calculus	3	3	0
	Physics 121, Introductory Analytical Physics I ...	3	3	2½
	Chemistry 105, General Inorganic Chemistry	3	2	3
	English 111, Introductory Course.....	3	3	0
	Engineering 3111, Drawing and Descriptive Geometry	3	1	5
	Engineering 3001, Introductory Engineering	1	2	0
	Total	16		

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 2	Mathematics 162, Analytic Geometry and Calculus	3	3	0
	Physics 122, Introductory Analytical Physics II	3	3	2½
	Chemistry 106, General Inorganic Chemistry	3	2	3
	English 112, Introductory Course	3	3	0
	Engineering 3112, Mechanical Drafting	3	1	5
	Engineering 3002, Introductory Engineering	2	2	0
	Total	17		

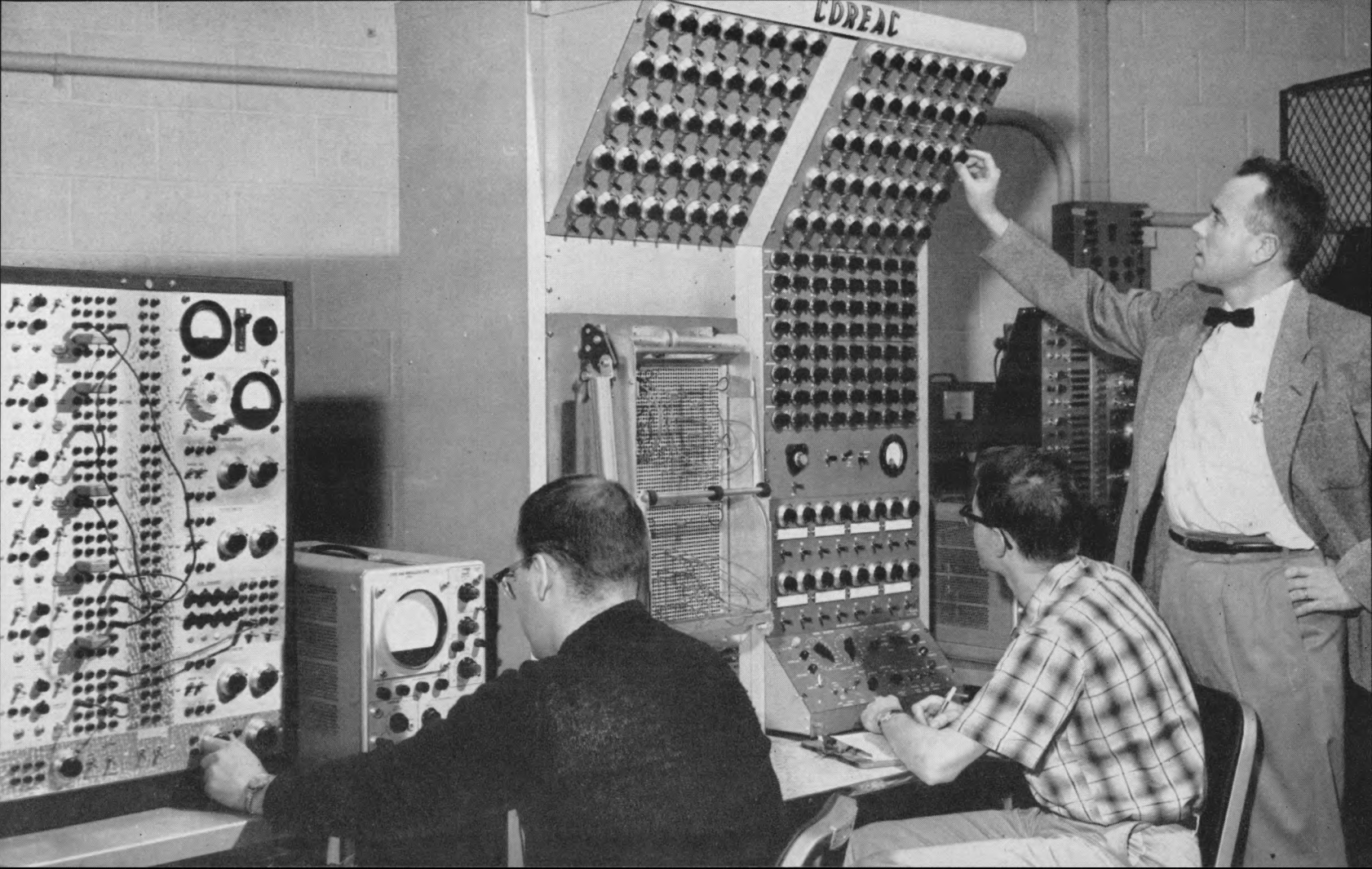
In addition to taking these courses, all freshmen must satisfy the University's requirements in physical education and in military training.

TERM 3	Mathematics 163, Analytic Geometry and Calculus	3	3	0
	Physics 123 or 125 or 127, Introductory Analytical Physics III	3	3	2½
	Chemistry 301, Organic Chemistry	2	2	0
	Engineering 1151, Mechanics—Statics	3	3	0
	Engineering 3241, Statistics	3	2	2½
	Engineering 6110, Casting, Working, and Welding of Metals (or Engineering 3406)	2	1	2
	Total	16		
TERM 4	Physics 124 or 126 or 128, Introductory Analytical Physics IV	3	3	2½
	Chemistry 402, Physical Chemistry	2	2	0
	Engineering 1153, Strength of Materials	3	2	2½
	Engineering 1155, Applied Mathematics	3	3	0
	Engineering 3262, Methods Engineering	3	1	5
	Engineering 3406, Materials Processing (or Engineering 6110)	2	1	2½
	Total	16		

In addition to taking these courses, all sophomores must satisfy the University's requirements in physical education and in military training.

TERM 5	Engineering 1241, Engineering Materials	3	2	2½
	Engineering 3351, Mechanism	3	2	2½
	Engineering 3601, Thermodynamics	3	3	0
	Engineering 1152, Mechanics—Dynamics	3	3	0
	Engineering 3246, Industrial Accounting	2	1	2½
	Engineering 3404, Production Machine Tools (or Engineering 3405)	2	1	2½
	Electives	3	Arr.	Arr.
	Total	19		

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 6	Engineering 1242, Engineering Materials	3	3	0
	Engineering 3352, Dynamics of Machinery	3	2	2½
	Engineering 3602, Thermodynamics	3	3	0
	Engineering 3603, Fluid Properties and Mass Flow	3	3	0
	Engineering 3247, Principles of Cost Control	3	2	2½
	Engineering 3405, Gage Laboratory (or Engineering 3404)	1	0	2½
	Electives	3	Arr.	Arr.
	Total	19		
TERM 7	Engineering 3604, Flow Processes and Energy Transfer	3	2	2½
	Engineering 3605, Heat Transfer	3	2	2½
	Engineering 3353, Design of Machine Members	3	2	2½
	Engineering 1243, Engineering Materials Laboratory	3	2	2½
	Engineering 3263, Production Engineering	3	2	2½
	Electives	3	Arr.	Arr.
	Total	18		
TERM 8	Engineering 3354, Design of Machines	3	1	5
	Engineering 4931, Electrical Engineering	3	2	2½
	Engineering 3264, Production Engineering	3	2	2½
	Engineering 3606, Thermal Engineering Laboratory	3	1	2½
	Engineering 6112, Metallurgy of Casting, Working, and Welding	2	2	0
	Electives (including Engineering 3607 or 3608 or 3609)	6	Arr.	Arr.
	Total	20		
TERM 9	Project	3	Arr.	Arr.
	Engineering 4932, Electrical Engineering	3	2	2½
	Engineering 1154, Strength of Materials	3	3	0
	Electives	11	Arr.	Arr.
	Total	20		
TERM 10	Project	3	Arr.	Arr.
	Engineering 4933, Electrical Engineering	3	2	2½
	Public Speaking 201	3	3	0
	Engineering 3041, Nonresident Lectures	1	1	0
	Electives	9	Arr.	Arr.
	Total	19		
	Total for ten terms	180		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SCHOOL OF ELECTRICAL ENGINEERING

FACILITIES

EARLY in 1955 the School of Electrical Engineering moved into Phillips Hall, a new building especially designed to house the School. Phillips Hall, the gift of Ellis L. Phillips, Cornell '95, provides ideal instructional, administrative, and research facilities. The library, established through a generous gift from the McGraw-Hill Book Company in memory of the first director of the School, and known as the Alexander Gray Memorial Library, is housed in Carpenter Hall as a part of the combined mechanical, electrical, and civil engineering library.

Laboratory facilities include the radio and communications laboratory; the microwave and ultra-high frequency laboratory; the vacuum tube laboratory; the electronics laboratory; the servomechanism laboratory; the industrial electronics laboratory; the electrical measurements and standardization laboratory; the electrical machinery laboratories; the illumination laboratory; the analog and digital computer laboratory; and the senior project laboratory for construction and testing of electronic apparatus by students according to their own designs.

In addition to these general laboratories, facilities available for instruction and research include the radio astronomy laboratory, engaged primarily in basic research; the antenna laboratory, for the investigation of directional characteristics of antennas; the ionospheric laboratory; the high voltage research laboratory; the a-c network calculator, designed to study problems arising in complex electrical networks; and the fluid network analyzer, designed to solve problems of pressure and flow in fluid distribution systems by means of electrical analogies.

The laboratories for instruction and research are supported by a well equipped model shop and a technicians' shop. These facilities provide a means of constructing experimental equipment in connection with senior projects and graduate theses, as well as for developing equipment for teaching laboratories and research projects.

PROGRAM OF STUDIES

The curriculum leading to the degree of Bachelor of Electrical Engineering is intended to create in the student an understanding of the

Students participating in the design and construction of the "Coreac," an analog computer in the School of Electrical Engineering.

meaning and the application of those laws of nature that are basic in the practice of electrical engineering and to develop a general knowledge of the origins and the trends of modern society. Through the first eight terms, all students follow the same program of technical studies; in the last two terms interest in one or more of the subdivisions of electrical engineering may be developed. Courses in nontechnical subjects are distributed throughout the curriculum in accordance with the student's increasing comprehension. In all, there are thirty-six hours of nontechnical courses in the curriculum. Of these, nine hours are specified, and twenty-seven are elective. In addition to these thirty-six hours, there are nine free elective hours that the student may take in nontechnical subjects if he so desires.

Students who show proficiency in the first term of the introductory course in English may substitute any nontechnical course for the second term of Introductory English.

The curriculum reflects the convictions of the faculty that the modern engineer is fully equipped only if his traditional ability to manage devices and processes is accompanied by a knowledge of men and an awareness of their needs.

INDUSTRIAL COOPERATIVE PROGRAM

The School participates in the Engineering Industrial Cooperative Program, providing periods of industrial experience interspersed among regular terms of study. The Program is described on page 13.

THE FRESHMAN YEAR

Since the curriculum of the freshman year in electrical engineering is essentially the same as the curricula in mechanical engineering and engineering physics, transfer of a student between any two of these curricula may occur before the third term without loss of time. The freshman curricula in civil engineering and in chemical and metallurgical engineering differ to such an extent from the curriculum in electrical engineering that a transfer into one of these curricula is almost certain to require a lengthening of the student's program.

CLASS ADVISERS

A member of the faculty experienced in dealing with freshmen is the adviser to each new freshman class that enters the School of Electrical Engineering. With the sophomore year the class is assigned to another adviser, who generally continues to serve until the class graduates, counseling each student in regard to curriculum, registration, scholarship, and other matters of the academic program. In addition, he tries to be helpful in the solution of personal problems that the student may bring to him.

Because responsibility for approval of the registration of each student is vested in the class adviser, no cancellation of courses or other changes in program may be initiated without his knowledge and approval. If the student desires a program of courses which the class adviser does not approve, the student may seek approval of the program by petition to the faculty of the School of Electrical Engineering.

SCHOLASTIC REQUIREMENTS

To remain in good standing, a student must either (1) pass the courses for which he is registered two weeks after the beginning of the term and have a weighted average of not less than 70 per cent; or (2) if one course is failed or is canceled, have a weighted average for the remaining courses of not less than 75 per cent. A student not meeting this requirement may be warned, placed on probation, or dropped from the School.

ELECTIVE COURSES

The curriculum in electrical engineering allows each student to choose a considerable number of elective courses during the later years of the curriculum. Some of the elective credit hours can be chosen without restriction; some must be nontechnical in the sense that they lie completely outside the field of engineering technology; and some must be either advanced courses in the sciences on which electrical engineering is based or in electrical engineering. The opportunity thus afforded for contact with the broader phases of education offered by the University as a whole tends to expand the student's mental horizon and to develop him as a responsible citizen.

The program of the fifth year includes two three-hour elective courses designated as "Project." A student makes his own selection of the topic or problem that he plans to investigate under the general supervision of a faculty member and prepares a project proposal for submission to his intended Project Supervisor. In choosing a topic and preparing a proposal, the student is expected to demonstrate the initiative and responsibility he will need to successfully complete the project. It is expected that each student will choose a problem closely related to his major interest in electrical engineering. If his proposal is not approved or if he does not elect to do a project, the student must elect six other technical elective hours.

There are a total of fifty-one elective credit hours in the curriculum in electrical engineering. Twenty-seven of these must be nontechnical, fifteen must be technical, and nine are completely free. In order to realize the objective of the curriculum to broaden the education of the student and at the same time provide some depth in the cultural subjects of his choice, the twenty-seven nontechnical elective hours must be selected as follows:

1. Nine hours elected from social studies with a 2-course sequence included;
2. Nine hours elected from the humanities with a 2-course sequence included;
3. Nine hours elected from any nontechnical course.

Fifteen elective credit hours (of which six may be Project) must be selected from courses in electrical engineering, mathematics, or physics. Of the total of fifteen, nine credit hours must be taken in electrical engineering. A course so selected must not contain a great amount of material that is essentially equivalent to that in required courses in the curriculum.

Acceptable courses are designated as follows:

1. Courses in electrical engineering numbered lower than 4900.
2. Courses in mathematics numbered higher than 300.
3. Courses in physics numbered higher than 209, except 226.

The courses, elected in fulfillment of the fifteen-hour technical elective requirement, serve as a core for advanced studies in a particular phase of electrical engineering. Students may specialize in radio and communications, in transistors and vacuum tubes, in industrial electronics and control, in power systems and machinery, in illumination, or in applied mathematics and physics. Alternately, some students find it advisable to take advanced courses that lie in more than one of these specialties.

In addition to the twenty-seven nontechnical elective hours enumerated above and the fifteen technical elective hours, there are nine free elective hours. These may be chosen from among any courses in the University for which prerequisites are satisfied, including those in the foregoing list. By carefully planning the use of electives, students may carry out extensive programs of study in other divisions of the University during the fifth year of the curriculum.

In many cases students choose to combine all or some portion of the free-elective requirements with the technical-elective requirements in order to emphasize certain studies in electrical engineering. Some of the many fields of studies along with their related courses are listed below. These groupings of courses are not intended to imply that a student must confine his studies to any one field but are presented for general information.

ELECTRIC NETWORK THEORY

4115—Principles of Nonlinear Circuits
4563—Signals and Noise in Communication Systems
4564—Transmission of Information
4571—Modern Network Analysis
4572—Modern Network Synthesis

ELECTRIC POWER SYSTEMS

4351—Power Systems I
4352—Power Systems II
4353—Power Systems III
4371—High-Voltage Phenomena (not offered in 1959–1960)

ELECTRONS AND WAVES

4526—Electron Dynamics
4527—Microwave Electronics
4561—Microwave Theory and Techniques
4565—Electromagnetic Theory
4529—Transistor Electronics

FEEDBACK CONTROL SYSTEMS

4711—Feedback Control Systems I
4712—Feedback Control Systems II
4810—Analog Computation
1175—Nonlinear Mechanics

ILLUMINATION

4611—Introductory Illumination
4612—Illumination Engineering
4615—Illumination Seminar
Phys. 216—Physical Optics
Psych. 207—Perception

INDUSTRIAL ELECTRONICS

4411—Electronic Control Equipment
4415—Advanced Electronic Controls
4421—Electronic Power Converters

NUCLEAR TECHNOLOGY

(The following courses constitute the core curriculum for the Engineering College Nuclear Technology Program.)
8301—Introduction to Atomic Nuclear Physics
8311—Nuclear and Reactor Physics
8351—Nuclear Measurements Laboratory
3605—Heat Transfer
6872—Nuclear Materials Technology
5760—Nuclear and Reactor Engineering

POWER MACHINERY

4321—Advanced Electrical Machine Theory
4326—Advanced Power Laboratory

COMMUNICATION SYSTEMS

4511—Radio Communication Theory I
4512—Radio Communication Theory II
4541—Applied Accoustics
4563—Signals and Noise in Communication Systems
4551—Radio Aids to Navigation

RADIO WAVE PROPAGATION

4565—Electromagnetic Theory
4568—Antennas
4566—Radio Waves I
4567—Radio Waves II

Credit hours in advanced military science and tactics or air or naval science may be counted, to the extent of nine, toward the requirements of the baccalaureate degree. These nine hours are considered to lie within the free-elective area of the curriculum.

COMBINED PROGRAMS IN LAW AND IN BUSINESS AND PUBLIC ADMINISTRATION

Students in the School of Electrical Engineering may apply for admission to special programs which will permit the completion of requirements for the B.E.E. degree in five years and the LL.B. in seven years or the M.B.A. or M.P.A. in six years. Such a program requires approval of the two schools involved and double registration in the fifth year. This results in reducing the time required for the second degree by a year.

CURRICULUM (B.E.E.)

		CREDIT HOURS	LEC. REC. HOURS	LAB. COMP. HOURS
TERM 1	Mathematics 161, Analytic Geometry and Calculus	3	3	0
	Physics 121, Introductory Analytical Physics I	3	3	2½
	Chemistry 105, General Chemistry	3	2	3
	Engineering 3117, Descriptive Geometry	2	0	5
	Engineering 3402, Machine Tool Processes	2	1	2½
	(*or* Engineering 6110, Casting, Working, and Welding of Metals)	(2)	(1)	(2)
	English 111, Introductory Course	3	3	0
	Total	16		

		CREDIT HOURS	LEC. REC. HOURS	LAB. COMP. HOURS
TERM 2	Mathematics 162, Analytic Geometry and Calculus	3	3	0
	Physics 122, Introductory Analytical Physics II	3	3	2½
	Chemistry 106, General Chemistry	3	2	3
	Engineering 3118, Mechanical Drafting	2	0	5
	Engineering 6110, Casting, Working, and Welding of Metals	2	1	2
	(*or* Engineering 3402, Machine Tool Processes)	(2)	(1)	(2½)
	English 112, Introductory Course	3	3	0
	Total	16		

In addition to these courses, all freshmen must satisfy the University's requirements in military training and physical education.

TERM 3	Mathematics 163, Analytic Geometry and Calculus	3	3	0
	Physics 123 or 125 or 127, Introductory Analytical Physics III	3	3	2½
	Engineering 1151, Mechanics	3	3	0
	Engineering 2131, Surveying	1	0	2½
	Nontechnical Elective	3	–	–
	Engineering 4101, Electrical Science I	3	4	0
	Total	16		
TERM 4	Engineering 4103, Mathematical Analysis of Linear Systems	3	2	2½
	Physics 124 or 126 or 128, Introductory Analytical Physics IV	3	3	2½
	Engineering 1152, Mechanics	3	3	0
	Engineering 3630, Engineering Thermodynamics	3	3	0
	Engineering 4102, Electrical Science II	3	4	0
	Total	15		

In addition to these courses, all sophomores must satisfy the University's requirements in military training and physical education.

TERM 5	Chemistry 401, Physical Chemistry	3	3	0
	Engineering 1153, Mechanics of Materials	3	2	2½
	Engineering 4112, Alternating Current Circuits	3	2	2½
	Engineering 4116, Electric Circuit Laboratory	3	1	3
	Nontechnical Electives	6	–	–
	Total	18		
TERM 6	Engineering 1241, Engineering Materials	3	2	2½
	Engineering 4113, Transmission Lines and Filters	3	2	2½
	Engineering 4121, Introduction to Electronics	4	3	2½
	Engineering 4216, Electrical Machinery Laboratory	4	2	3
	Nontechnical Elective	3	–	–
	Total	17		

		CREDIT HOURS	LEC. REC. HOURS	LAB. COMP. HOURS
TERM 7	Engineering 2331, Fluid Mechanics (or 3341)	3	3	0
	Engineering 4123, Electronic Circuits	4	3	2½
	Engineering 4221, Alternating Current Machinery	4	2	3
	Engineering 4114, Transients in Linear Systems	3	2	2½
	Nontechnical Elective	3	–	–
	Total	17		
TERM 8	Physics 214, Atomic, Nuclear, and Electron Physics	3	3	0
	Engineering 3341, Machine Design (or 2331)	4	3	2½
	Engineering 4123, Electronic Circuit Elements	4	3	2½
	Engineering 4226, Electrical Machinery Laboratory	4	2	3
	Nontechnical Elective	3	–	–
	Total	18		
TERM 9	Engineering 4021, Technical Writing and Presentation	3	3	0
	Free Electives	6	–	–
	Nontechnical Elective	3	–	–
	Senior Project 4091 (or Technical Elective)	3	–	–
	Technical Elective	3	–	–
	Nonresident Lectures 4041	1	1	0
	Total	19		
TERM 10	Free Elective	3	–	–
	Nontechnical Electives	6	–	–
	Senior Project 4092 (or Technical Elective)	3	–	–
	Technical Electives	6	–	–
	Total	18		
	Total for 10 Terms	170		

GRADUATE WORK IN THE SCHOOL OF ELECTRICAL ENGINEERING

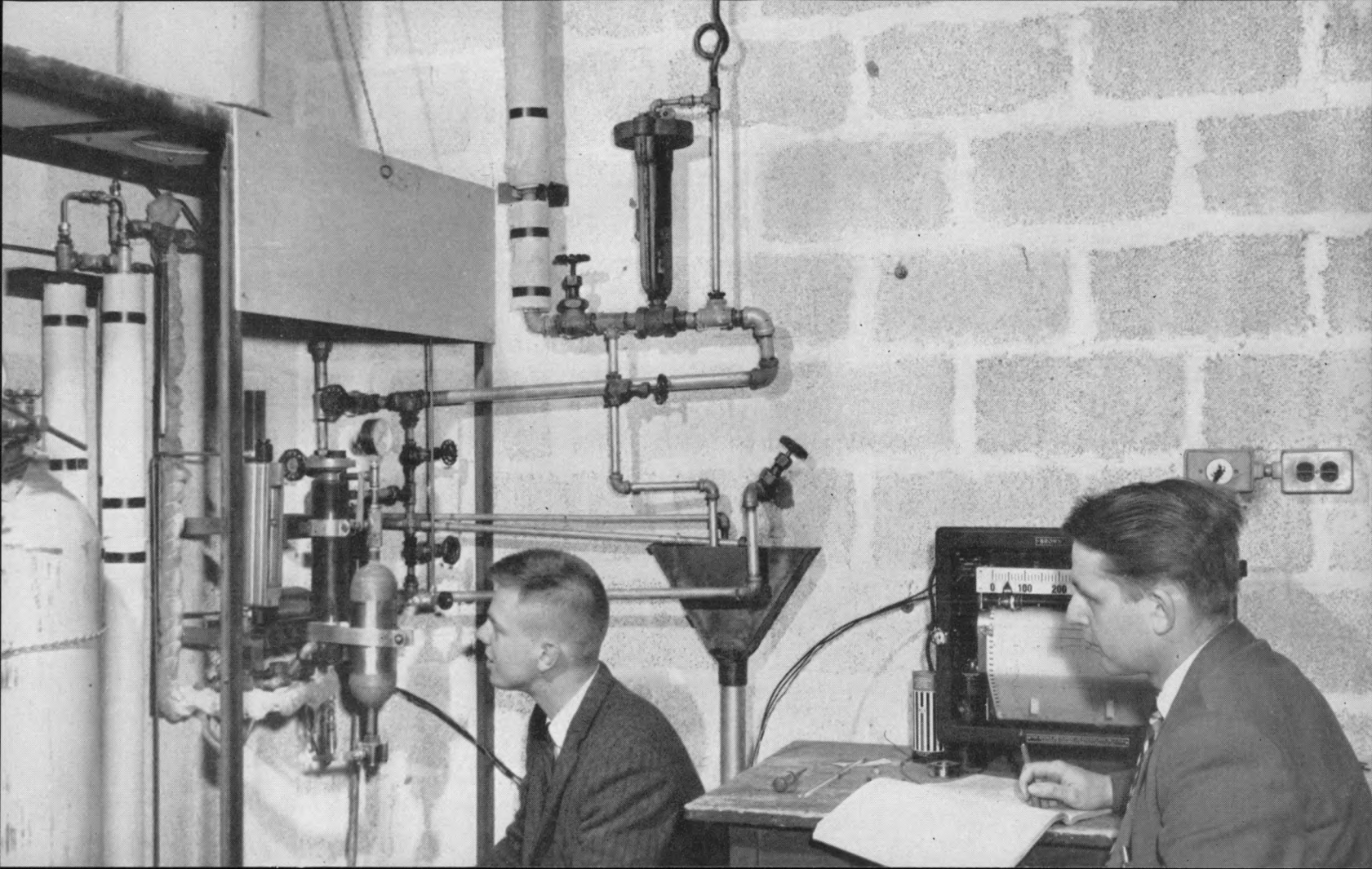
Graduate work may be undertaken in the School of Electrical Engineering for the degrees of Doctor of Philosophy, Master of Science, and Master of Electrical Engineering. The degrees of Doctor of Philosophy and Master of Science are administered by the Graduate School for all departments of the University, and the regulations for these degrees are described in the *Announcement of the Graduate School.* They are research degrees that involve residence on the campus and submission of a thesis. In the School of Electrical Engineering research work leading to these degrees may be undertaken in communications, microwaves, vacuum tubes, transistors, radio transmission in the atmosphere, electromagnetic methods for investigating space, radio astronomy, elec-

tric network theory, feedback control systems, electrical machines, power transmission, computers, etc. Fellowships, research assistantships, and teaching assistantships are available in limited numbers to candidates for the degrees of Doctor of Philosophy and Master of Science who are doing their thesis research in the School of Electrical Engineering.

The degree of Master of Electrical Engineering is available as a curriculum type of professional degree at the Master's level, the general requirements for which are stated on page 15. Of the 45 credit hours stated in the general requirements, the M.E.E. degree requires 6 hours of project 4091 and 4092, 12 hours in electrical engineering taken from the courses listed below, 6 hours taken in physics courses numbered higher than 209 except 226, 6 hours of advanced mathematics courses numbered higher than 306, and 15 hours from any of the aforementioned groups.

4090	4352	4511	4541	4567	4615
4115	4353	4512	4551	4568	4711
4123	4371	4516	4561	4571	4712
4226	4411	4517	4563	4572	4713
4321	4415	4526	4564	4581	4810
4326	4421	4527	4565	4611	4820
4351	4501	4529	4566	4612	

It is possible for a specially qualified student to earn the M.E.E. in one semester after receiving the five-year B.E.E. degree by properly choosing his elective courses so as to meet the above requirements. If this is done, all but ten of the above required hours can be completed within the normal ten terms, leaving these ten for the eleventh term. In the eleventh term, five completely free elective hours must also be taken to meet the requirement of the Graduate School that fifteen credit hours be taken for a full semester's work beyond the baccalaureate. All course work to be counted toward the M.E.E. degree requirements must be passed with a minimum grade of 80.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SCHOOL OF CHEMICAL AND METALLURGICAL ENGINEERING

FACILITIES

THE SPECIALIZED training in chemical and metallurgical engineering is given in Olin Hall of Chemical Engineering and in the laboratories for foundry practice and metal working. The courses in chemistry are given in Baker Laboratory of Chemistry.

Olin Hall of Chemical Engineering was provided through the generosity of Franklin W. Olin, Cornell '86, as a memorial to his son Franklin W. Olin, Jr., Cornell '12. This modern and well equipped building, with 105,000 square feet of available floor space, provides lecture rooms, recitation rooms, and laboratories for instruction and research in chemical and metallurgical engineering.

The unit operations laboratory, one hundred feet long and fifty feet wide, extends through three floors and houses semiplant-scale equipment for both instruction and research in chemical engineering. It is served by a traveling crane and by its own shops and analytical laboratory. Twenty-five small laboratories provide research facilities for both undergraduate and graduate students. Olin Hall also contains special research laboratories such as the Geer Laboratory for Rubber and Plastics, biochemical engineering laboratories, and rooms and equipment for studying instrumentation and automation, microscopy, the use of radioactive material, etc.

The unit processes laboratory of metallurgical engineering offers facilities for instruction and research in ore dressing, furnace design, atmosphere control, smelting and refining, electrodeposition and heat treatment. Equipment is also available for forming metals mechanically by means of drawing, rolling or forging, or by powder metallurgy processes.

The laboratories for physical metallurgy and metallography are equipped with metallurgical microscopes and metallographs and with supplementary equipment for sample preparation and testing. X-ray diffraction equipment is available for supplementing the microscopical techniques.

The welding and grazing laboratories include facilities for manual and automatic arc welding, gas welding and brazing, inert-gas-shielded

Fifth year chemical engineering students operating research equipment which they designed and constructed to investigate a new method of producing polyethylene.

arc welding, atomic-hydrogen arc welding, resistance spot welding, and gas cutting.

In the foundry laboratories, melting facilities include an electric arc furnace, cupola furnace, and numerous gas-fired and crucible furnaces. Molding may be done manually or by machine, utilizing a variety of molding techniques, including shell-molding and plaster-of-paris molding. Diecasting and permanent mold casting facilities are also available.

CHEMICAL ENGINEERING

PROGRAM OF STUDIES

Cornell University inaugurated a five-year curriculum in chemical engineering in 1932. Long experience with the five-year course has proved its value in offering excellent opportunities to the undergraduate student to obtain thorough training in his chosen field. The five-year program in chemical engineering permits a greater amount of study in nontechnical fields, plus the opportunity to take more specialized work in the later years. Project courses in research and design are given in the fifth year after a student has completed most of his basic work. Such projects require the application of much of the subject matter covered in the basic courses and point out the engineer's need for a firm foundation in the sciences.

The School of Chemical and Metallurgical Engineering has the excellent cooperation of strong departments of chemistry, mathematics, and physics, the sciences that make up most of the course work of the first two years. Chemical engineering has always been closely allied with chemistry, and undergraduate students in chemical engineering complete the basic chemistry required of a chemistry major in the College of Arts and Sciences. Advanced chemistry courses may be elected in the last two years.

Instruction in the basic principles of chemical engineering starts in the second year and extends through the fifth year. Each succeeding year both extends and broadens the scope of the chemical engineering courses so that a student has the proper training to handle advanced work in his field. The project courses in the fifth year are designed to encourage individual work and initiative under conditions that are equivalent to those found in the process industries.

Courses in English, speech, and history totaling fifteen credits are required. In addition, twelve credits of electives must be taken in nontechnical fields of study such as literature and languages, history, philosophy, sociology, psychology, economics, etc. Three credits of nontechnical electives are taken in the freshman year along with the courses in English. A total of twenty-six credits of electives are reserved

for the fourth and fifth years. They are reserved for the later years so that better selection may be made because of the greater maturity and experience possessed by students at this level. Selected specialization in advanced courses is possible since basic work has been completed. No restrictions are placed on the choice of electives, but each student must submit a co-ordinated plan indicating the electives he proposes to take and outlining the objectives to be achieved. This planned program must include a sequence of study to complete the minimum requirement of nine additional credit hours of nontechnical courses. Many students choose all their electives outside engineering.

OPTIONS

Specialized work is offered in biochemical engineering, petroleum, plastics and rubbers, business administration, nuclear engineering, instrumentation and automation, industrial and engineering administration, and reaction kinetics. The two-year sequence of electives at an advanced level allows students to arrange programs that are the equivalent of options in these fields. The exact sequence of courses to be selected for advanced training is not specified, since it depends on the student's interests and capabilities. Exceptional students are allowed to register for graduate courses in these fields.

Those students in chemical engineering who are interested particularly in the financial and administrative aspects of engineering may register jointly in the School of Chemical and Metallurgical Engineering and in the Graduate School of Business and Public Administration during their fourth and fifth years and may then, by continuing in the Graduate School of Business and Public Administration for one additional year after receiving the first degree in engineering, be awarded the degree of Master of Business Administration or Master of Public Administration. In this way it is possible for a student to receive both the degree in engineering and the degree in business or public administration after a total period of residence of six years.

Students in chemical engineering who contemplate entering the legal profession may register jointly in the School of Chemical and Metallurgical Engineering and in the Law School of Cornell University in the fifth year of the course in chemical engineering and may count this year of work toward the degree of Bachelor of Laws as well as toward the degree in engineering.

EMPLOYMENT AFTER GRADUATION

Graduates in chemical engineering find employment in the design, development, operation, and administration of chemical engineering plants. There is also a demand for men with chemical engineering training for technical sales work in the chemical industries and for edi-

torial work on technical publications. Some graduates in chemical engineering continue their specialized training as graduate students in chemistry or chemical engineering to prepare for positions as research chemists or research engineers. Among the major fields of employment for graduate engineers today are the manufacture of synthetic organic chemicals; plastics, synthetic fibers, and rubber; petroleum refining; soap and detergents; etc. Many groups of industries that, in former years, had need for only a few men with chemical engineering training are today requiring such men in increasing number. Among these relatively new fields of major employment are the food industries, the atomic-power industry, and the recovery and purification of the several so-called "rare" or "unusual" metals that are becoming increasingly important. Nearly thirty years of experience with the Cornell five-year course in chemical engineering has caused employers of graduates to offer starting salaries comparable to those usually given to holders of Masters' degrees.

SCHOLASTIC REQUIREMENTS

A student in the School of Chemical and Metallurgical Engineering who does not receive a passing grade in every course for which he is registered, or who fails in any term or summer session to maintain an average grade of 75, may be dropped or placed on probation.

If, in the opinion of the faculty, a student's general record is unsatisfactory, the student may be refused permission to continue his course even though he has met the minimum requirements in respect to the number of hours of work passed and the grades in those hours. Students who fall behind in their work may be warned, put on probation, or dropped, either from an individual course or from the University, at any time during the term.

Students who so desire may change from the curriculum in chemical engineering to that in metallurgical engineering, or from the curriculum in metallurgical engineering to that in chemical engineering, at any time before the beginning of the fifth semester without loss of time or credit.

CURRICULUM (B.Ch.E.)

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 1	Chemistry 113, Introductory Inorganic Chemistry	4	3	3
	Physics 121, Introductory Analytical Physics I...	3	3	2½
	Mathematics 161, Analytic Geometry and Calculus	3	3	0
	English 111, Introductory Course.....	3	3	0
	Engineering 3119, Drawing and Descriptive Geometry	2	0	4
	Engineering 5000, Orientation	0	1	0
	Total	15		
TERM 2	Chemistry 114, Introductory Chemistry.....	4	2	6
	Physics 122, Introductory Analytical Physics II...	3	3	2½
	Mathematics 162, Analytic Geometry and Calculus	3	3	0
	English 112, Introductory Course.....	3	3	0
	Engineering 3120, Drawing and Descriptive Geometry	1	0	2½
	Engineering 5000, Orientation.....	0	1	0
	Nontechnical elective	3	0	0
	Total	17		

In addition to taking the above courses, all freshmen must satisfy the University's requirements in physical education and military training.

TERM 3	Mathematics 163, Analytic Geometry and Calculus	3	3	0
	Chemistry 307, Introductory Organic Chemistry..	3	3	0
	Chemistry 311, Organic Chemistry Laboratory...	2	0	6
	Chemistry 224, Introductory Quantitative Analysis	4	2	6
	Engineering 5101, Introductory Chemical Engineering	2	2	0
	Physics 123 or 125 or 127, Introductory Analytical Physics III	3	3	2½
	Total	17		
TERM 4	Engineering 1156, Applied Mathematics	3	3	0
	Chemistry 308, Introductory Organic Chemistry..	3	3	0
	Chemistry 312, Organic Chemistry Laboratory ..	2	0	6
	Engineering 5102, Introductory Chemical Engineering	2	2	0
	Engineering 1151, Mechanics	3	3	0
	Physics 124 or 126 or 128, Introductory Analytical Physics IV	3	3	2½
	Public Speaking 201	3	3	0
	Total	19		

In addition to taking the above courses, all sophomores must satisfy the University's requirements in physical education and military training.

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 5	Chemistry 403, Physical Chemistry	3	3	0
	Chemistry 411, Physical Chemistry Laboratory	2	1	2½
	Engineering 1152, Mechanics	3	3	0
	Engineering 5203, Chemical Processes	2	2	0
	Engineering 5303, Unit Operations	3	3	0
	Engineering 5851, Chemical Microscopy	3 or 0	1	5
	Engineering 3241, Statistics	0 or 3	2	2½
	History 165, Science in Western Civilization	3	3	0
	Total	19		
TERM 6	Chemistry 404, Physical Chemistry	3	3	0
	Chemistry 412, Physical Chemistry Laboratory	2	1	2½
	Engineering 1153, Strength of Materials	3	3	0
	Engineering 5204, Chemical Processes	2	2	0
	Engineering 5304, Unit Operations	3	3	0
	Engineering 5851, Chemical Microscopy	0 or 3	1	5
	Engineering 3241, Statistics	3 or 0	2	2½
	History 166, Science in Western Civilization	3	3	0
	Total	19		
TERM 7	Engineering 4931, Electrical Engineering	3	2	2½
	Engineering 5103, Chemical Engineering Thermodynamics	3	3	0
	Engineering 5353, Unit Operations Laboratory	3	2	3
	Engineering 5711, Library Use and Patent Law	2	2	0
	Engineering 6255, Materials of Construction	3	3	0
	Electives	5	–	–
	Total	19		
TERM 8	Engineering 4933, Electrical Engineering	3	2	2½
	Engineering 5104, Chemical Engineering Thermodynamics	3	3	0
	Engineering 5354, Unit Operations Laboratory	3	2	3
	Engineering 5701, Plant Inspection Trip	1	1	0
	Engineering 6256, Materials of Construction	3	3	0
	Electives	6	–	–
	Total	19		
TERM 9	Engineering 5503, Chemical Engineering Calculations	2	2	0
	Engineering 5106, Reaction Kinetics	2	2	0
	Engineering 5746, Chemical Engineering Economics	3	3	0
	Engineering 5953, Research Project	2	0	6
	Chemistry 555,* Advanced Inorganic Chemistry	3	3	0
	Electives	6	–	–
	Total	18		

*Not required until 1961–1962. Suggested as an elective for fall of 1959 and 1960.

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 10	Engineering 5504, Chemical Engineering Calculations	2	2	0
	Engineering 5610, Plant Design Project	4	2	6
	Engineering 5954, Research Project	2	0	6
	Electives	9	–	–
	Total	17		
	Total for 10 terms	179		

REQUIREMENTS FOR THE DEGREE OF M.Ch.E.

A candidate must complete a minimum of 54 credit hours distributed as follows (see page 15 for additional information):

1. A minimum of 18 credit hours in the basic physical sciences of physics, chemistry, and mathematics. Normally, 6 credit hours of mathematics, and 3 to 9 credits in both physics and chemistry, must be selected from the following courses to make up the total of 18 credits (see the *Announcement of the College of Arts and Sciences* for descriptions of courses numbered below 1000):

Chemistry (3 to 9 credits): 245, 320, 365, 366, 375, 380, 395, 431, 448, 455, 461, 472, 480, 482, 491, 492, 555, 575, 576, 585, 586; Biochemistry 101, 102, 201, 202.

Physics (3 to 9 credits): 214, 225, 226, 236, 243, 244, 254, 350, 380, 675, 775, 8311, 8312, 8313, 8321, 8351, 8352, 8512.

Mathematics (6 credits): 501–502, 609, 610, 612, 613, 614, 615, 616, 621–622, 641–642, 661, 662, 5508, 5509.

2. At least 18 credits in chemical engineering selected from the following courses: 6255–6, 5104, 5106, 5108, 5503–4, 5505, 5506, 5605–6–7–8+, 5609, 5741, 5742, 5743, 5744, 5746, 5747, 5748, 5749, 5760, 5851, 5953–4–5–6+, 6872.

Normally, a student will be expected to complete 5503–4 and a project course (marked +).

3. To complete degree requirements, all courses in excess of the minimum 36 hours specified above are considered to be electives even if they are taken in the basic sciences or chemical engineering. Graduate courses in other divisions of the College of Engineering are acceptable electives. All elective courses must be approved by the student's adviser and the Graduate Committee of the School.

SPECIALIZED TRAINING

Within the basic requirements for the degree of M.Ch.E., programs may be arranged which give the student advanced training in various

specialized fields employing chemical engineers. They may be planned to meet the requirements and special interests of the individual student. Specific programs are available in biochemical engineering, chemical engineering administration, nuclear engineering, and polymeric materials, but others may be arranged.

METALLURGICAL ENGINEERING

Metallurgical engineering is concerned with the science and technology of metals and related materials, including:

a. Extracting and purifying metals from ores that occur naturally.
b. Alloying metals with other metals, or nonmetals, to develop desirable properties, such as strength, corrosion resistance, or heat resistance.
c. Heat-treating metals to develop optimum properties for varied uses.
d. Casting or mechanically forming metals into useful shapes, such as engine blocks, railroad rails, or airplane parts.
e. Joining metals to other metals by welding or brazing.
f. Selection of metals and alloys for specific applications, e.g., chemical process vessels or nuclear power reactors.

Since the field is very broad, it is often differentiated into three divisions, concerned respectively with extractive metallurgy, physical metallurgy, and mechanical metallurgy. The first stems principally from the basic science of chemistry, the second from the basic science of physics, and the last from physics and the applied science of mechanics. Extractive metallurgy involves the reactions and processes familiar to the chemist and chemical engineer and is sometimes called chemical metallurgy. Physical metallurgy involves study of the internal structure of metals as affected by alloying, heat treatment, and deformation, and the dependence of properties and behavior on internal structure. Mechanical metallurgy is closely related to other engineering fields and involves the shaping of metal into useful parts, such as structural beams, aircraft propellers and jet engine blades, communication cable, etc. Metal processing methods such as casting, mechanical forming, and welding are included in the broad classification of mechanical metallurgy.

The selection of metals for specific types of service brings the metallurgical engineer into association with all fields of engineering, since metals are the most important class of materials for engineering construction.

PROGRAM OF STUDIES

The curriculum leading to the degree of Bachelor of Metallurgical Engineering provides a broad coverage of the theoretical and applied

aspects of all branches of metallurgical engineering, built upon intensive training in the basic sciences—mathematics, physics, and chemistry—and in allied fields of engineering.

Basic subjects consume the major part of the first two years, with metallurgical courses beginning in the second year to give an introduction to extractive and physical metallurgy and metal processing. The metallurgical content of the curriculum progressively increases in the last three years, with emphasis on basic principles and correlation of information.

During the fifth year, each student, working under the direction of a member of the faculty, carries on a research project in a special area of his own selection. The project may be in any field of metallurgical activity, ranging from theoretical science to applied engineering.

The sequence of courses is closely coordinated to provide a broad fundamental background on which to undertake work in any branch of metallurgical engineering. Graduates are qualified for work in extractive, physical, or mechanical metallurgy, as well as for graduate study.

TECHNICAL AND NONTECHNICAL ELECTIVES

The program in metallurgical engineering offers a core of required basic and applied courses and provides for a large number of elective choices. The student may use the elective hours to supplement the required courses with more advanced sequential study in the basic sciences or in metallurgical and other engineering fields, or to pursue other subjects of special interest outside engineering.

At least one elective choice is available in each term after the first term of the freshman year. In the last two years of the program, a large number of elective hours make it possible for the student to take advanced courses in specific scientific and technical areas and to study in other divisions of the University. Thus he may elect advanced courses in metallurgical engineering, or courses in nontechnical areas. He may also elect a sequence of courses in a specific technology, e.g., nuclear technology; he may co-register in the Law School or the Graduate School of Business and Public Administration; or he may pursue advanced courses in mathematics, physics, and chemistry in preparation for graduate study.

The curriculum provides for a minimum of 27 hours of nontechnical courses essential to a liberal education. Of these, 15 are specified as introductory English, speech, and history of science in Western civilization. The remaining 12 are to be chosen by the student, in consultation with his adviser, from the fields of the humanities and social sciences, including the classics, economics, English, fine arts, government, history, language, literature, philosophy, psychology, and sociology.

Of the remaining elective hours, twelve must be technical in nature, selected from the basic sciences, mathematics, chemistry, physics; or from metallurgical or other fields of engineering; or from approved courses in other divisions of the University.

The remaining seventeen elective hours may be selected as the student, with the guidance of his adviser, sees fit. These may be selected in any area of the University for which the prerequisites are met. Some students use these free elective hours to fulfill a portion of the requirements of programs in law, business or public administration, or the professional Master's degree in engineering (M.Met.E.).

OPTIONS AND COMBINED PROGRAMS

Students in metallurgical engineering may utilize their elective hours to take specialized and sequential work in such fields as business administration, law, industrial and labor relations, nuclear technology, and materials technology.

The sequence in nuclear technology, for example, includes courses in nuclear and reactor physics, nuclear measurements, and heat transfer. The program, described in detail elsewhere in this Announcement, prepares students for work in the design, development, and operation of nuclear reactors.

The metallurgical engineering student wishing to gain a broader training in materials technology may elect courses concerned with ceramics, nuclear materials, high temperature materials, polymeric materials, concrete, foundry engineering, materials processing, and others.

Students interested particularly in administrative aspects of engineering may co-register in the Graduate School of Business and Public Administration during their fourth and fifth years and may then, by continuing in the latter school for one additional year after receiving the degree of B.Met.E., be awarded the degree of Master of Business Administration or Master of Public Administration.

Students who contemplate entering the legal profession may register jointly in the Law School in their fifth year in metallurgical engineering, and may count this year of work toward both the engineering degree and the degree of Bachelor of Laws. During the sixth and seventh years, and after receiving the degree of B.Met.E., the student is registered only in the Law School.

EMPLOYMENT AFTER GRADUATION

Since metals play an important role in almost every kind of engineering activity, graduates of the curriculum in metallurgical engineering have an unexcelled diversity of opportunities for employment. Metallurgical engineers are employed in basic metallurgical industries, such as those producing steel, copper, or aluminum. In these industries,

graduates may be concerned with smelting and refining operations and with the production of finished or semifinished products. They may be concerned with research and development, plant operations, or technical sales.

Metallurgical engineers are also in demand in industries that fabricate or consume metals. For example, they may work in the chemical process or petroleum industries, advising as to the most suitable material for a specific operation and seeing that performance is satisfactory. Metallurgical engineers also may work in the automobile, aircraft, or electronic industries, all-important consumers of metals and thus dependent upon proper selection and utilization of metals.

Graduates also may enter the utilities industries which furnish transportation, communication, and power. Opportunities are excellent for metallurgical engineers in the nuclear engineering field, because of the many challenging materials problems concerned with manufacture of fuel elements and reactor vessels, as well as with piping, heat exchangers, and more conventional parts. The field of high-speed flight of aircraft and missiles also presents challenging problems in the need for heat-resistant materials.

Opportunities are good in basic and applied research and development in both primary producing as well as consuming industries or in government laboratories concerned with civilian or defense needs.

TRANSFER INTO METALLURGICAL ENGINEERING

A number of students fail to recognize an interest in metallurgical engineering before embarking on some other engineering program. Owing to the large number of elective hours and the flexability in the curriculum thereby afforded, a student may transfer into metallurgical engineering at the end of the freshman year, and in most instances even at the end of the second year, without over-all loss of time.

SCHOLASTIC REQUIREMENTS

The scholastic requirements in metallurgical engineering are identical with those in chemical engineering (see page 58 of this Announcement).

METALLURGICAL ENGINEERING CURRICULUM (B.Met.E.)

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 1	Chemistry 113, Introductory Inorganic Chemistry	4	3	3
	Physics 121, Introductory Analytical Physics I	3	3	2½
	Mathematics 161, Analytic Geometry, Calculus	3	3	0
	English 111, Introductory Course	3	3	0
	Engineering 3119, Drawing and Descriptive Geometry	2	0	4
	Engineering 6000, Orientation	0	1	0
		15		
TERM 2	Chemistry 114, Introductory Chemistry	4	2	6
	Physics 122, Introductory Analytical Physics II	3	3	2½
	Mathematics 162, Analytic Geometry and Calculus	3	3	0
	English 112, Introductory Course	3	3	0
	Engineering 3120, Drawing and Descriptive Geometry	1	0	2½
	Engineering 6001, Orientation	0	1	0
	Elective	3		
		17		

In addition to taking the above courses, all freshmen must satisfy the University's requirements in physical education and military training.

TERM 3	Mathematics 163, Analytic Geometry and Calculus	3	3	0
	Chemistry 224, Introductory Quantitative Analysis	4	2	6
	Chemistry 301, Introduction to Organic Chemistry	2	2	0
	Physics 123, 125 or 127, Introductory Analytical Physics III	3	3	2½
	Engineering 6201, Production of Metals	3	3	0
	Engineering 6251, Metallurgy Laboratory	1	0	2½
	Elective	3		
		19		
TERM 4	Physics 124, 126 or 128, Introductory Analytical Physics IV	3	3	2½
	Engineering 1156, Applied Mathematics	3	3	0
	Engineering 1151, Mechanics-Statics	3	3	0
	Engineering 6202, Nature and Utilization of Metals	3	3	0
	Engineering 6252, Metallurgy Laboratory	2	1	2½
	Elective	3		
		17		

In addition to taking the above courses, all sophomores must satisfy the University's requirements in physical education and military training.

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 5	Chemistry 403, Introductory Physical Chemistry	3	3	0
	Chemistry 411, Physical Chemistry Laboratory	2	1	2½
	Engineering 5851, Chemical Microscopy	3	1	5
	Engineering 6301, Principles of Metallurgical Engineering	3	3	0
	History 165, Science in Western Civilization	3	3	0
	Elective	3		
		17		
TERM 6	Chemistry 404, Introductory Physical Chemistry	3	3	0
	Chemistry 412, Physical Chemistry Laboratory	2	1	2½
	Engineering 1153, Strength of Materials	3	2	2½
	History 166, Science in Western Civilization	3	3	0
	Engineering 6353, Introductory Metallography	3	1	5
	Elective	3		
		17		
TERM 7	Engineering 6403, Metallurgical Thermodynamics	3	3	0
	Engineering 6415, Principles of Materials Processing	3	2	2½
	Engineering 6411, Physical Metallurgy	3	3	0
	Chemistry 555, Advanced Inorganic Chemistry	3	3	0
	Engineering 1152, Mechanics—Dynamics	3	3	0
	Elective	3		
		18		
TERM 8	Engineering 6404, Metallurgical Thermodynamics	3	3	0
	Engineering 6452, Experimental Physical Metallurgy	3	2	2½
	Engineering 6412, Physical Metallurgy	3	3	0
	Engineering 6471, Plant Inspections	1	–	–
	Speech 201	3	3	0
	Electives	6		
		19		
TERM 9	Engineering 4931, Electrical Engineering	3	2	2½
	Engineering 6553, Metallurgical Engineering Project	2	–	6
	Engineering 3241, Statistics	3	2	2½
	Engineering 6503, Service Behavior of Metals	3	3	0
	Electives	8	–	
		19		
TERM 10	Engineering 4933, Electrical Engineering	3	2	2½
	Engineering 6506, Metallurgical Design	2	2	0
	Engineering 6554, Metallurgical Engineering Project	2	–	6
	Engineering 6504, Unit Processes	3	1	2½
	Electives	9		
		19		
	Total for 10 Terms	177		

REQUIREMENTS FOR THE DEGREE OF M.Met.E.

A candidate must complete a minimum of 54 credit hours distributed as follows:

1. A minimum of 18 credit hours in the basic physical sciences of physics, chemistry, and mathematics. Normally, 6 credit hours of mathematics, and 3 to 9 credits in both physics and chemistry should be selected. The courses that may be taken will ordinarily fall within the following list (see the *Announcement of the College of Arts and Sciences* for descriptions of those numbered below 1000):

Chemistry: 431, 455, 461, 472, 480, 485, 491, 492, 555, 575, 576, 585, 586.

Physics: 214, 225, 226, 236, 243–244, 254, 350, 380, 477, 485, 486, 588, 675, 676, 775, 8121–8122, 8252, 8311, 8312, 8313, 8321, 8351, 8512, 8517.

Mathematics: 501–502, 609–610, 612, 613, 614, 615, 616, 621–622, 641–642, 661, 662, 721, 5508, 5509.

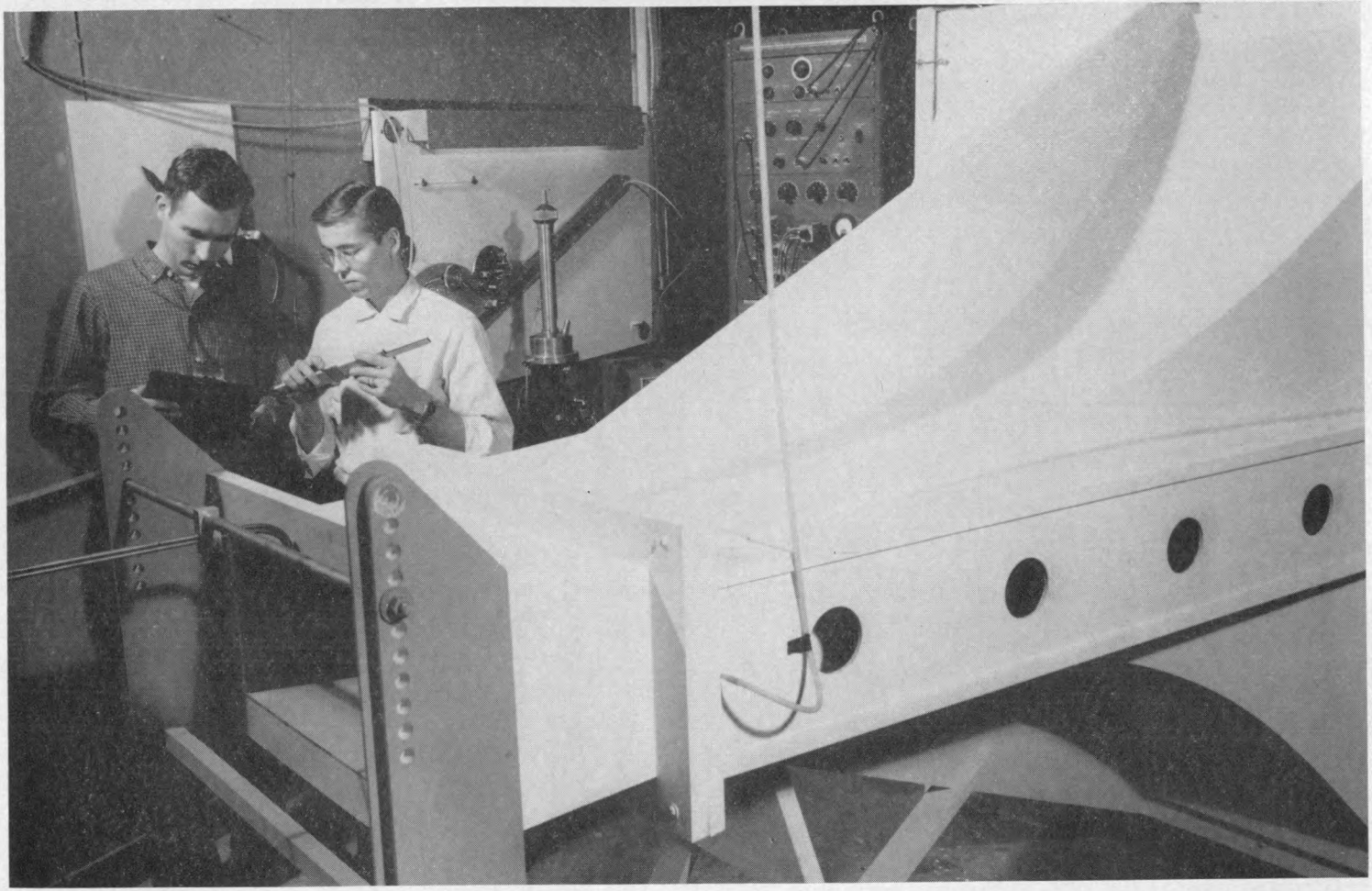
2. A minimum of 18 credits in metallurgical engineering selected from the following list of courses: 6404, 6501, 6502, 6553–6556, 6620, 6623, 6624, 6641, 6651, 6661, 6671, 6872, 6960, 6970.

A student transferring from another school, after consultation with the faculty, may find it advisable to include in his plan of study certain undergraduate courses in metallurgical engineering or portions thereof, for which he will not receive advanced credit.

3. A minimum of 18 credit hours of elected courses, of which 9 may be nontechnical; courses in the basic physical sciences or in metallurgical engineering in excess of the minimum requirements are considered electives for the purpose of meeting this requirement. All elective courses must be approved by the student's adviser and the Graduate Committee of the School.

SPECIALIZED TRAINING

A student may select his program within the above framework of required and elective courses to provide for specialized training in business or public administration or in the application of metals to specific industries, such as the chemical or nuclear power industries, as well as in other fields.



THE GRADUATE SCHOOL OF AERONAUTICAL ENGINEERING

THE PRIMARY objective of this School is the training of selected engineering and science graduates in the scientific aspects of aeronautics. This training is intended especially to prepare the students to carry out research and development engineering in the aeronautical and "aero-space" industries and in the related scientific institutions.

To this end, students are admitted to this School who have demonstrated, in their undergraduate careers, more than average abilities in analytical subjects, and who have shown adequate promise of carrying on graduate study successfully.

In the aeronautical engineering program, considerable emphasis is placed upon original research, both theoretical and experimental. Through the academic year, close contact is maintained between the Graduate School at the University and the Cornell Aeronautical Laboratory in Buffalo, N.Y. In addition, certain periods of employment at the Laboratory are offered to aeronautical engineering students—usually during their summer vacations. Students are urged to take advantage of such employment, if it is available.

The Graduate School of Aeronautical Engineering is in the newly completed Grumman Hall, the gift of Leroy R. Grumman, Cornell '16. In these new quarters the School is provided with superior facilities for laboratory studies in fluid mechanics, aerodynamics, and gasdynamics. Members of the teaching staff and graduate students are engaged in an active program of fundamental studies in these fields. Emphasis is put upon the scientific and engineering problems of space flight, i.e., of vehicles which leave and re-enter the earth's atmosphere at extreme speeds.

ADMISSION

Application for admission to the Graduate School of Aeronautical Engineering as a candidate for the degree M.Aero.E. should be made to the Director of the Graduate School of Aeronautical Engineering, College of Engineering, Cornell University. A special application blank for this purpose can be obtained from the Office of the Director of the Graduate School of Aeronautical Engineering and should be returned directly to him.

Data from this cascade wind tunnel are important in the preliminary design of jet and turboprop aircraft engines.

The degree of M.Aero.E. is awarded under the jurisdiction of the College of Engineering, and therefore candidates for this degree do not register in the Graduate School of the University.

Students who desire to work for the degree of Ph.D. with aeronautical engineering as their major subject must be admitted to the Graduate School of the University in the usual manner. They should make application to the Dean of the Graduate School, using the application blank for admission to the Graduate School.

CURRICULUM

The aeronautical engineering curriculum is planned to accomplish the broad objectives stated above. Courses of study are provided leading to the degree of Master of Aeronautical Engineering and to the degree of Doctor of Philosophy with aeronautical engineering as the major subject.

STUDY LEADING TO THE DEGREE OF M.AERO.E.

This program of aeronautical engineering studies is applicable to much of the standard engineering work in the aeronautical industry, but beyond that it is planned to increase the student's facility in the use of the basic sciences in aero-space engineering and to stimulate growth in the performance of independent research and development work. Because the progress in this field is so extremely rapid, it is an essential objective of this program to go beyond the study of present-day practices and techniques and to prepare the student in the fundamental background and analytical methods that can be adapted to future development.

1. *THE CURRICULUM REQUIREMENT* for the degree M.Aero.E. is the successful passing of a series of courses or examinations in these subjects. The list of subjects reproduced below constitutes a standard of accomplishment for the M.Aero.E. candidate, but the faculty will modify the list to suit the needs, interests, and background of each individual candidate. Sufficient course offerings are available to permit candidates to study in any of three areas of aeronautical engineering: (1) aerodynamics, (2) gasdynamics (aerophysics), (3) aeronautical structures. Active research in all three areas is being carried out in the School.

Although the standard list of required subjects is such as ordinarily to occupy (together with the thesis) four terms of graduate study, the residence requirement has been set at one year (two terms), so that students who enter the School with exceptional preparation, or are able otherwise to pass the required examinations, may be able to qualify for the degree in one year.

When the student desires to satisfy a requirement by examination (rather than by passing a course), he should request the faculty of the School to schedule such an examination.

It is suggested that each candidate supplement his required program of courses, e.g., the standard list below, by additional courses either in aeronautical engineering or in other fields of study, so as to result in a balanced program of twelve to sixteen credit hours per term.

2. *AN ACCEPTABLE MASTER'S THESIS,* based upon original research, is required of each candidate for the M.Aero.E.

3. *M.AERO.E. CANDIDATES MUST PASS A FINAL EXAMINATION,* either oral or both oral and written, administered by the faculty of aeronautical engineering. The faculty will frequently invite other members of the University staff to attend and to participate in such examinations.

STANDARD LIST OF REQUIRED SUBJECTS FOR THE M.AERO.E. DEGREE

	CREDIT HOURS
Mathematics 609 and 610, Higher Calculus for Engineers and Physicists	6
or	
Engineering 1180, 1181, Advanced Engineering Mathematics	6
Engineering 7101, Mechanics of Airplanes and Missiles	3
Engineering 7102, Mechanics of Airplanes and Missiles	3
or	
Engineering 4991, Electronic Engineering	3
Engineering 7203 and 7204, Gasdynamics	6
Engineering 7301, Theoretical Aerodynamics I	3
Engineering 7403 and 7404, Aircraft Design	2
Engineering 7405, Aero-Elastic Problems	3
Electives chosen from List A below	12

ELECTIVES: LIST A

Engineering 7206, Introduction to Magnetohydrodynamics	2
Engineering 7302, Theoretical Aerodynamics II (Wing Theory)	3
Engineering 7303, Theoretical Aerodynamics III (Compressible Fluids)	3
Engineering 7304, Theoretical Aerodynamics IV (Viscous Fluids)	3
Engineering 7306, Theory of Propellers and Rotors	1
Engineering 1162, Mechanics of Vibration	3
Engineering 1163, 1164, Applied Elasticity	3, 3
Engineering 1165, Mathematical Elasticity	3
Engineering 1167, Plates and Shells	3
Engineering 1168, Plasticity and Stability	3
Engineering 1170, Advanced Mechanics	3
Engineering 1172, Selected Topics in Engineering Mechanics	(arranged)
Engineering 1175, 1176, Introduction to Nonlinear Mechanics	3, 3
Engineering 3652, Combustion Theory	3
Engineering 4565, Electromagnetic Theory	3
Mathematics 621–2, Mathematical Methods in Physics	4, 4
Mathematics 641–2, Partial Differential Equations	3, 3

	CREDIT HOURS
Physics 242, Analytical Mechanics	3
Physics 243–4, Atomic and Molecular Physics	6
Physics 254, Electronic Properties of Solids and Liquids	3
Physics 380, Special Laboratory Work	(arranged)
Physics 475, Theoretical Mechanics	3
Physics 476, Electrodynamics	3

STUDY LEADING TO THE DEGREE OF Ph.D.

Students will be admitted to candidacy for the degree of Ph.D. as set forth in the current *Announcement of the Graduate School.* General requirements such as residence, major and minor subjects, foreign languages, qualifying examinations, and thesis are also explained there. Each candidate is required to complete a schedule of courses acceptable to his Special Committee, as explained in the *Announcement.*

PREPARATION FOR GRADUATE STUDY

The Graduate School of Aeronautical Engineering will admit students holding baccalaureate degrees in any branch of engineering, physics, or mathematics, provided that their undergraduate scholastic records are such as to indicate ability to handle graduate study. The Cornell courses of study in engineering physics, electrical engineering, and mechanical engineering are especially recommended to students who expect to enter this School after graduation.

All students who expect to enter the Graduate School of Aeronautical Engineering should try to arrange their undergraduate programs to include as much work as possible in applied mechanics, thermodynamics, mathematical analysis, and physics. In most cases, it will be well for engineering students to elect courses in intermediate or advanced physics, such as atomic and molecular physics, kinetic theory of gases, and electricity and magnetism.

It will be possible for Cornell students in the five-year undergraduate programs to complete the requirements for the degree M.Aero.E. in one year of graduate study instead of the normal two years, if they complete a sufficient number of the required graduate courses as electives in their undergraduate programs. The following courses are recommended for this purpose:

Engineering 7101, 7102	Mechanics of Airplanes and Missiles
Engineering 7203, 7204	Gasdynamics
Mathematics 609, 610	Higher Calculus for Engineers and Physicists
or	
Mathematics 621, 622	Mathematical Methods in Physics
Engineering 7403, 7404	Aircraft Design

Engineering 1170	Advanced Mechanics
Engineering 1162	Mechanics of Vibration
Physics 242	Analytical Mechanics
Physics 243, 244	Atomic, Molecular, and Nuclear Physics

To be admitted to graduate courses, an undergraduate student must (1) be a regularly enrolled student in at least the seventh term of one of the engineering, physics, or mathematics curricula at Cornell University; (2) show promise, by his previous scholastic record or otherwise, of ability satisfactorily to pursue advanced study and research; and (3) have his admission to the courses recommended by the Director of the Graduate School of Aeronautical Engineering (or the chairman of the department concerned).

DEPARTMENT OF ENGINEERING PHYSICS

OBJECTIVES

THE DEPARTMENT of Engineering Physics, recently established, is so constituted as to provide a type of education and training which will effectively bridge the gap between that of the basic sciences and that of conventional engineering practice. The general aim is to prepare students for a prospective career in technical research and advanced engineering development. As a result of the expanding technological activities in the country, the industrial research laboratories and engineering development laboratories are in urgent need of graduates with the vigorous and exacting course of study which the curriculum of this department provides.

FACULTY

The administrative arrangement of the Department is such that the faculty of the Department includes members of the science departments of the College of Arts and Sciences and members of the several schools of engineering in the College of Engineering who are particularly interested in the objectives of the Department.

LABORATORY FACILITIES

The Department of Engineering Physics has a fully equipped laboratory of electron microscopy, including four large research-type electron microscopes and equipment for research both on the instrument itself and on applications to problems in physics, chemistry, biology, and engineering materials. Facilities are also available for study in applied electron optics.

The Department also maintains a laboratory with much special equipment for the study of the elastic properties of single metal crystals, of elastomers, plastics and similar materials, and of other phenomena related to the physics of the solid state. Extensive research is carried on in the field of surface physics and corrosion, making use of ultra high vacuum techniques, microbalance, electron diffraction, field emission microscope, etc.

Counting activated gold foils to determine neutron flux levels.

Recently, a laboratory of nuclear measurements has been established as part of the nuclear technology program. In addition to a nuclear subcritical assembly containing two and one-half tons of natural uranium, the laboratory is well equipped with Geiger counters and scalers, a 5′ x 5′ x 7′ graphite "sigma pile," neutron sources, linear amplifiers, and so on, for experimental work associated with the rapidly expanding field of applied nuclear physics. Construction of a teaching and research reactor and of a critical facility will be begun by early 1960.

In addition, students carrying out their project studies have access to the other laboratories of the College of Engineering and to those of the College of Arts and Sciences as may be desirable.

PROGRAM OF STUDIES

The curriculum leading to the degree of Bachelor of Engineering Physics covers intensive study over a five-year period. The course of study is designed to combine the broad, basic, scientific, and analytical training of the physicist with the knowledge of the properties of materials and the technological principles of the engineer. The subject matter falls into three main categories: fundamental sciences, namely, mathematics, physics, and chemistry; the properties and treatment of material; and engineering practice.

For training in engineering research and development, the student terminates the course by carrying out a semiresearch project in a special field of his own choice, under the direction of a faculty member who is an authority in the selected field. There are a great variety of these special fields in physical science and engineering. They include topics in electron physics, atomic and nuclear physics, reactor technology, nuclear instrumentation, electron optics, and applications including electron microscopy, X-rays and crystal structure, spectroscopy, engineering electronics, communications, servomechanisms, ultra high frequency generation and propagation, circuit analysis, elasticity and stress analyses, properties of materials, engineering mechanics, physical metallurgy, thermodynamics and heat transfer, aerodynamics, airplane structure, etc.

SCIENTIFIC AND TECHNICAL ELECTIVES

Considerable flexibility in the technical courses is provided in the last few terms of the curriculum to allow the student to advance in some technical fields beyond the level provided by the required courses as his interest in such fields develops. To permit this, eighteen hours are provided to cover the semiresearch project and the technical electives which may be selected, with the permission of the student's adviser, from the following subjects: physics, mathematics, chemistry, physical metallurgy, advanced mechanics and elasticity, engineering materials,

fluid mechanics, aerodynamics, heat power, communications, industrial electronics, servomechanism theory, ultra high frequency. The choice will depend largely on the student's particular ability or interest. At least one of the technical electives, with a minimum of 3 credit hours, must include advanced laboratory work.

By suitable selection of technical electives during his last two years of candidacy for the B.Eng.Phys. degree, the qualified student may obtain an unusually sound and well rounded education preparing him for a career in one of the many specialized fields of engineering. Here are two examples:

Aeronautical Engineering. A properly qualified student may elect courses given in the Graduate School of Aeronautical Engineering and thus obtain an excellent preparation in aeronautical engineering at the undergraduate level. Also, this procedure will shorten the time required to complete the requirements for the M.Aero.E. degree if the student wishes to continue study in that field. Details of this arrangement are described on page 74.

Nuclear Technology. It is possible to choose electives so as to provide a well rounded and extensive education for a career in the nuclear energy field or in nuclear reactor power developments. Courses in reactor physics, in nuclear measurements, in thermonuclear power principles, in advanced heat transfer, and in physics of solids underlying radiation damage problems are available. Attention is directed to courses 8311, 8312, 8313, 8351, 8352, and 8321, and to 3665, 5760, and 6872, which are described in detail in the section "Description of Courses." Additional closely related courses such as Physics 244 are also available.

Space Science and Technology. Engineering physics, with its strong emphasis on basic sciences, provides an excellent preparation for specialization in this field of unlimited possibilities, during the last two undergraduate years or during graduate studies. Courses in gas-dynamics, radio wave propagation, optics, astronomy, relativity, and many others can be taken as electives by qualified students. Several faculty members have strong research interests in this field and are available to supervise senior research projects related to their area of specialization.

Members of the faculty will assist the student in planning a special program in his particular field of interest.

NONTECHNICAL ELECTIVES

The curriculum provides for a minimum of thirty hours of courses that broaden the student's liberal education. Of these, twelve hours are specified as introductory English and modern foreign languages, and eighteen hours are to be chosen by the student in consultation with his adviser.

These electives may be chosen from subjects such as the following: astronomy, biology, botany, the classics, economics, English, fine arts, government, history, languages, literature, music appreciation, philosophy, psychology, sociology, speech. The opportunity thus afforded for contact with the broader phases of education offered by the University as a whole assists in expanding the student's mental horizon and in developing him as a well-rounded citizen. In order to emphasize the broadening of the student's background, at least six hours have to be chosen in each of two fields within the humanities, the social sciences, and history (see the *Announcement of the College of Arts and Sciences*).

Students who pass the proficiency examination of the Department of Modern Languages and do not wish to continue the study of a language may substitute six hours of other liberal electives in place of the language requirement. Students who wish to continue the modern language studied in high school will be asked to take a placement examination at the University, unless they have taken the College Board Achievement Test in that language. Students who show proficiency in the first term of the introductory course in English may be permitted, with the consent of the Department of English, to substitute other courses in English or English literature in the second term.

ADDITIONAL ELECTIVES

In addition, twelve hours of free electives are provided, which may be chosen from any courses in the University that are open to the student, except, however, that not more than six credit hours toward the baccalaureate degree will be allowed in advanced military science and tactics or in naval science.

CLASS ADVISERS

Members of each entering class in the engineering physics curriculum are assigned to an experienced faculty member who will counsel and supervise each student in matters connected with choice of elective courses, registration, scholarship, and other matters of importance encountered during the student's entire college career. The personal relationship between the adviser and the student and the adviser's intimate knowledge of the student's academic performance can be of great help to the student in obtaining the best results from his university training.

SCHOLASTIC REQUIREMENTS

A student enrolled in the engineering physics curriculum is expected to maintain the following minimum scholastic requirements: (1) receive a passing grade in every course for which he is registered; (2) maintain

each term a weighted average of at least 75%; and (3) exhibit natural aptitude and competence in the basic subject matter of the curriculum.

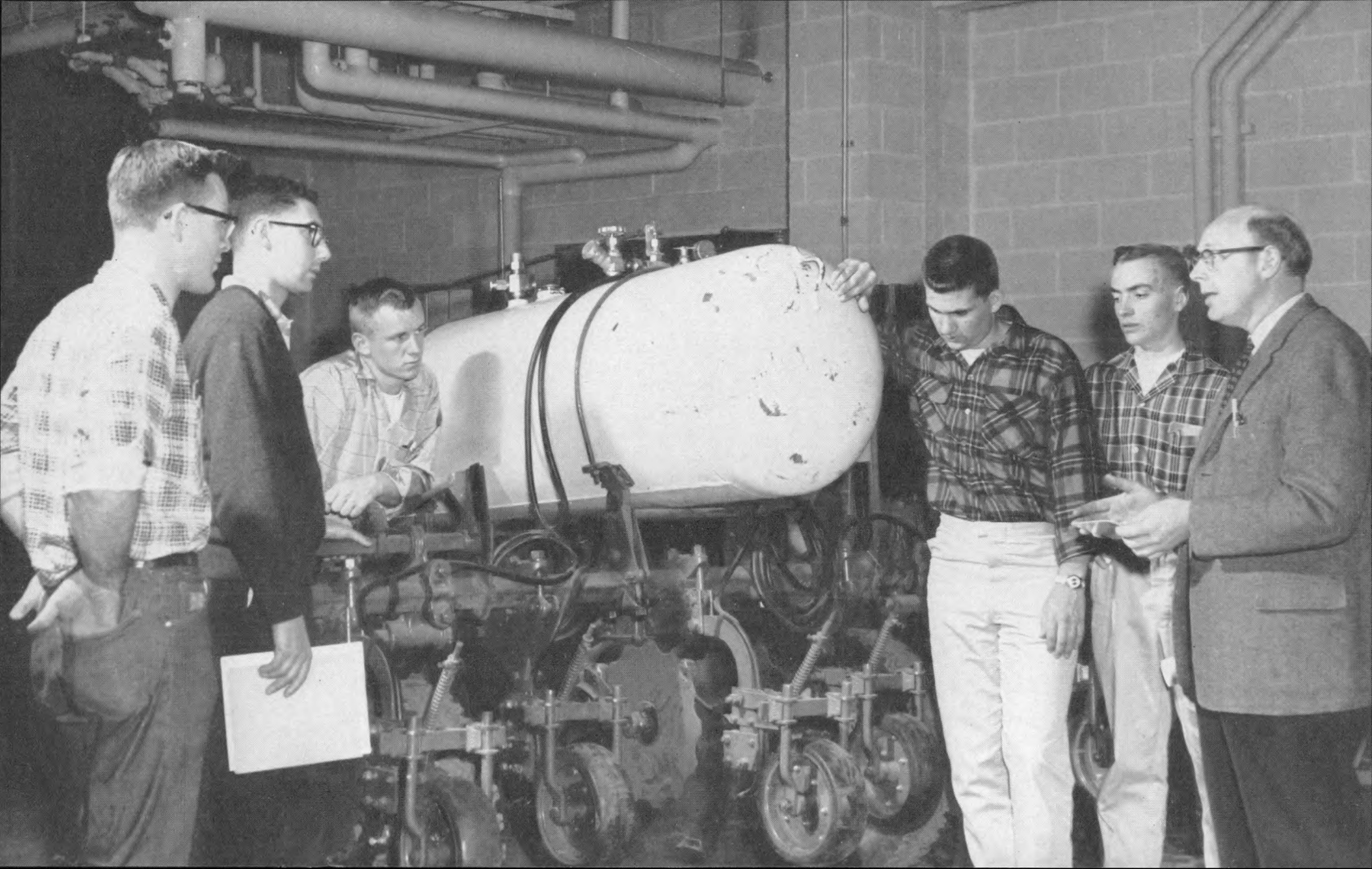
A student failing to satisfy these requirements may be put on probation or refused permission to continue his studies in the Department.

ENGINEERING PHYSICS CURRICULUM

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 1	Mathematics 161, Analytic Geometry and Calculus	3	3	0
	Physics 121, Introductory Analytical Physics I...	3	3	2½
	Chemistry 105, General Chemistry	3	3	2½
	English 111, Introductory Course	3	3	0
	Engineering 3117, Drawing and Descriptive Geometry	2	0	5
	Liberal elective	3	3	0
	Total	17		
TERM 2	Mathematics 182, Analytic Geometry and Calculus	3	3	0
	Physics 122, Introductory Analytical Physics II ...	3	3	2½
	Chemistry 106, General Chemistry	3	2	3
	English 112, Introductory Course	3	3	0
	Engineering 3118, Drawing and Descriptive Geometry	2	0	5
	Engineering 3403, Fundamentals of Machine Tools	1	1	1½
	Elective	3		
	Total	18		
TERM 3	Mathematics 183, Analytic Geometry and Calculus	3	3	0
	Physics 123 or 125 or 127, Introductory Analytical Physics III	3	3	2½
	Engineering 1151, Statics..	3	3	0
	A modern foreign language	6	2	6
	Engineering 6110, Casting, Working and Welding of Metals	2	1	2
	Total	17		
TERM 4	Mathematics 612, Methods of Applied Mathematics	3	3	0
	Physics 124 or 126 or 128, Introductory Analytical Physics IV	3	3	2½
	Chemistry 402, Introduction to Physical Chemistry	3	3	0
	Engineering 1152, Dynamics	3	3	0
	Engineering 4983, Basic Electrical Engineering....	4	3	2½
	Total	16		

In addition to these courses, students must satisfy the University's requirements in military training and physical education for the first four terms.

		CONTACT HOURS		
		CREDIT HOURS	LEC. REC.	LAB. COMP.
TERM 5	Mathematics 613, Methods of Applied Mathematics	3	3	0
	Physics 225, Electricity and Magnetism	3	3	0
	Engineering 8121, Thermodynamics and Kinetic Theory	3	3	0
	Engineering 4116, Electric-Circuit Laboratory	3	1	3
	Engineering 1153, Mechanics of Materials	3	2	2½
	Elective	3		
	Total	18		
TERM 6	Mathematics 614, Methods of Applied Mathematics	3	3	0
	Physics 242, Analytical Mechanics	3	3	0
	Engineering 8122, Thermodynamics and Kinetic Theory	3	3	0
	Engineering 4121, Electron Tubes and Circuits	4	2	5
	Elective	3		
	Total	16		
TERM 7	Mathematics 615, Methods of Applied Mathematics	3	3	0
	Physics 243, Atomic and Molecular Physics	3	3	0
	Engineering 1201, Engineering Materials	4	3	2½
	Engineering 4122, Electronic Circuit Elements	4	2	5
	Elective	3		
	Total	17		
TERM 8	Mathematics 616, Methods of Applied Mathematics	3	3	0
	Physics 254, Electronic Properties of Solids and Liquids	3	3	0
	Physics 210, Advanced Laboratory	3	0	5
	Chemistry 416, Chemical Bonding and Physical Properties of Organic Molecules	3	3	0
	Electives	6		
	Total	18		
TERM 9	Engineering 8252, Selected Topics in Physics of Engineering Materials	3	3	0
	Engineering 8051, Project	3		
	Electives	9		
	Total	15		
TERM 10	Engineering 8131, Mechanics of Continuum	3	3	0
	Engineering 8052, Project	3		
	Electives	12		
	Total	18		



AGRICULTURAL ENGINEERING

A JOINT program administered by the Colleges of Agriculture and Engineering leads to the degree of Bachelor of Agricultural Engineering. Students in this curriculum register in the College of Agriculture during the first four years but take courses in the Colleges of Engineering, Arts and Sciences, and Agriculture. Registration for the fifth and final year is in the College of Engineering, which grants the degree.

The purpose of this curriculum is to train engineers for service in the agriculutral industry in such fields as power and machinery, structures, soil and water engineering, electrification, and the processing and handling of agricultural products. Modern mechanized agriculture is dependent upon the products and services of many industries and organizations to supply food and fiber to an ever-increasing population.

Graduates in agricultural engineering find ready employment in the manufacturing industry, in the food processing and marketing industry, in public service utilities, in consulting and farm-management services, and many others. Educational institutions and governmental agencies have continued need for research engineers in investigations related to irrigation, to water conservation and control, to soil management, to machinery for handling new and specialized crops, and in problems related to structures and to labor efficiency in the production and management of crops and livestock. Colleges and universities must also continue to provide teachers for training new engineers.

FACILITIES

The Department of Agricultural Engineering moved into Riley-Robb Hall, a new and excellently equipped building, in 1956. This building provides complete facilities for teaching, extension, and research programs. The laboratories provide adequate space and the latest equipment for teaching in all fields of agricultural engineering and food technology.

ADMISSION REQUIREMENTS

Requirements for entrance to this curriculum are the same as those for mechanical, civil, and electrical engineering. Since, however, it is

Studying specialized farm machinery design requirements in an agricultural engineering laboratory.

the purpose of this curriculum to train engineers for agriculture, careful attention will be given to evidence of interest in and background for the work on the part of applicants.

OUTLINE OF INSTRUCTION

The curriculum leading to the degree of Bachelor of Agricultural Engineering requires five years of study. Subject matter is drawn from five basic fields of study:

1. Basic science (mathematics, chemistry, physics, biology, bacteriology, geology)

2. Engineering science (mechanics, property of materials, thermodynamics, heat transfer, electrical theory)

3. Engineering application (structural design, hydraulics, surveying, power, machinery design, water control and management)

4. Agriculture (soils, field crops, livestock feeding, farm management)

5. General studies (English, public speaking, social sciences, economics)

Students in this curriculum are required to meet the practice requirement of the College of Agriculture (see the *Announcement of the New York State College of Agriculture).*

SCHOLASTIC REQUIREMENTS

To remain in good standing, a student must have a weighted average for the term of 70 or above. If the weighted average is 60 or higher, but less than 70, the student will be placed on probation. A student will be dropped from the program if a third consecutive term of probation is indicated or if the weighted average is below 60. In all cases, the student may appeal an action by presenting new information to the Joint Faculty Committee.

CURRICULUM (B.Agr.E.)

(For a complete description of the courses in agriculture, see the *Announcement of the College of Agriculture.)*

			CONTACT HOURS	
		CREDIT HOURS	LEC. REC.	LAB. COMP.
TERM 1	Mathematics 161, Analytic Geometry and Calculus	3	3	0
	Physics 121, Introductory Analytical Physics I...	3	3	2½
	Chemistry 105, General Inorganic Chemistry	3	2	3
	English 111, Introductory Course	3	3	0
	Engineering 3111, Drawing and Descriptive Geometry	3	1	5
	Agriculture 1, Orientation	1	1	0
	Total	16		

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 2	Mathematics 162, Analytic Geometry and Calculus	3	3	0
	Physics 122, Introductory Analytical Physics II	3	3	2½
	Chemistry 106, General Inorganic Chemistry	3	2	3
	English 112, Introductory Course	3	3	0
	Engineering 3112, Mechanical Drafting	3	1	5
	Agr. Engineering 2, Introduction to Agricultural Engineering	2	2	0
	Total	17		

In addition to these courses, all freshmen must satisfy the University's requirements in military training and physical education.

Farm practice is required. See the *Announcement of the College of Agriculture.*

TERM 3	Mathematics 163, Analytic Geometry and Calculus	3	3	0
	Physics 123 or 125 or 127, Introductory Analytical Physics III	3	3	2½
	Chemistry 301, Organic Chemistry	2	2	0
	Engineering 1151, Mechanics—Statics	3	3	0
	Biology 1, General Biology	3	2	2½
	Geology 115, Elementary Geology	3	2	2½
	Total	17		
TERM 4	Physics 124 or 126 or 128, Introductory Analytical Physics IV	3	3	2½
	Chemistry 402, Physical Chemistry	2	2	0
	Engineering 1155, Applied Mathematics	3	3	0
	Engineering 1153, Strength of Materials	3	3	0
	Engineering 2132, Surveying	3	3	2½
	Biology 1, General Biology	3	2	2½
	Total	17		

In addition to these courses, all sophomores must satisfy the University's requirements in military training and physical education.

TERM 5	Engineering 1241, Materials of Construction	3	2	2½
	Animal Husbandry 10, Livestock Feeding	4	3	2½
	Engineering 2731, Elements of Structural Engineering I	3	2	2½
	Agronomy 1, Nature and Properties of Soils	5	5	2½
	Engineering 1152, Mechanics—Dynamics	3	3	0
	Total	18		
TERM 6	Engineering 3341, Machine Design	4	3	2½
	Engineering 1242, Materials of Construction	3	2	2½
	Engineering 2301, Elementary Fluid Mechanics	3	3	0
	Agricultural Bacteriology 3	3	3	0
	Agricultural Bacteriology Lab. 5	1	0	4
	Engineering 2732, Elements of Structural Engineering II	3	2	2½
	Total	17		

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 7	Engineering 2715, Reinforced Concrete Design	3	0	6
	Engineering 3601, Thermodynamics	3	3	0
	Agronomy 11, Production of Field Crops	4	3	2½
	Social science elective	3	3	0
	Engineering 2302, Applied Hydraulics and Hydrology	3	2	2½
	Total	16		
TERM 8	Engineering 3602, Engineering Thermodynamics	3	2	2½
	Agr. Engineering 221, Soils and Water Engineering	3	2	2½
	Agr. Economics 102, Farm Management	5	3	3
	Agr. Engineering 203, Agricultural Machinery Design	3	2	2½
	Social Science Elective (preferably Economics)	3	3	0
	Total	17		

Summer: Six-week term. No. 206, Field Problems in Agricultural Engineering. Credit 6 hours.

TERM 9	Engineering 3605, Heat Transfer	3	2	2½
	Engineering 4931, Electrical Engineering	3	2	2½
	Extension Teaching 101, Oral and Written Exp.	2	2	0
	Agr. Engineering 202, Farm Power	3	2	2½
	Agr. Engineering 253, Special Topics	1	Arr.	Arr.
	Elective	6	Arr.	Arr.
	Total	18		
TERM 10	Engineering 3609, Refrigeration and Air Conditioning	3	3	0
	Engineering 4932, Electrical Engineering	3	2	2½
	Agr. Engineering 231, Farm Structures Design	3	2	2½
	Agr. Engineering 253, Special Topics	1	Arr.	Arr.
	Elective	9	Arr.	Arr.
	Total	19		
	Total for Ten Terms	178		

DESCRIPTION OF COURSES

THE COURSES listed in the preceding curricula are described in the sections following. Courses are described under the heading of the school or college in which they are offered. Courses in chemistry, English, mathematics, physics, and certain courses in economics are offered by the College of Arts and Sciences. Courses in military training and physical education, under the direct supervision of the University as a whole, are listed in a general section.

The courses designated by four digit numbers are offered by the College of Engineering. The first digit represents the school or department. Descriptions of courses will be found in the section of this Announcement as follows:

1. Engineering Mechanics and Materials
2. Civil Engineering
3. Mechanical Engineering
4. Electrical Engineering
5. Chemical Engineering
6. Metallurgical Engineering
7. Aeronautical Engineering
8. Engineering Physics

General courses of instruction required by some or all of the schools within the College of Engineering but given in other colleges of the University are described on pages 135–145.

For courses in other colleges not described here, to be taken as electives, see the Announcement of the appropriate college.

ENGINEERING MECHANICS AND MATERIALS

Courses described in this section are given by the Department of Engineering Mechanics and Materials. They constitute a major part of the stem of basic engineering science prescribed for all engineering students and are directed toward the development of fundamental background for application to all phases of engineering work.

Advanced and graduate courses in these fields are also included in this section.

Messrs. Bijlaard, Block, Conway, Cranch, Cuykendall, Dally, Jeffrey, Mason, Mitchell, Moynihan, Pao, Perkins, Peterson, Ruoff, Sack, Slate, and Wiegandt.

1134. *ADVANCED STRENGTH OF MATERIALS.* Credit 3 hrs. 1 Lect. 2 Rec. Prereq., 1153. Strain energy methods. Castigliano's theorem. Reciprocal theorem. Deflection of beams. Conjugate beam method. Beams of uniform strength. Maximum

moment due to traveling loads. Influence of shear deformation. Curved beams. Arches. Buckling of columns with various end conditions. Energy methods. Combined axial and lateral loads. Strength theories. Fatigue. Impact. High temperatures. Thick tubes under internal and external pressure. Clamped and continuous beams. Bending of beams not following Hooke's law. Reinforced concrete beams. Shear center of beams. Bending of circular plates.

1145. *APPLIED DIFFERENTIAL EQUATIONS.* Credit 3 hrs. 1 Lect. 2 Rec. Prereq., Mathematics 163 and 1151. Elementary ordinary and partial differentiai equations, Fourier series, and engineering applications in civil engineering fields.

1151. *MECHANICS OF ENGINEERING—STATICS.* Credit 3 hrs. 1 Lect. 2 Rec. Prereq., Physics 121 and parallel registration in Mathematics 163. The principles of statics of particles, chains, and rigid bodies. Equilibrium, friction, centroids, moments and products of inertia, virtual displacements, graphical methods, three dimensional trusses and frames. Vector methods.

1152. *MECHANICS OF ENGINEERING—DYNAMICS.* Credit 3 hrs. 1 Lect. 2 Rec. Prereq., 1151, 1153 and 1155, 1145, or 1156, or parallel registration in Mathematics 607. The principles of dynamics of particles and rigid bodies. Rectilinear, curvilinear, rotational, and general plane motion of rigid bodies. Vector methods. (The section of this course for agriculture and civil engineering students is offered in the spring term only and does not require 1155 as a prerequisite.)

1153. *MECHANICS OF MATERIALS.* Credit 3 hrs. 1 Lect. 2 Rec. 1 Lab. Prereq., 1151. Stress and strain, tension, compression, and shear, rivited and welded joints, elementary beam theory, combined stresses, columns, strain energy, beams on several supports.

1154. *ADVANCED STRENGTH OF MATERIALS.* Credit 3 hrs. 1 Lect. 2 Rec. Prereq., 1153 and 1155. Strength, stiffness, and stability of machine parts, disks, plates, shells, thick cylinders, straight and curved beams; principal stresses in two and three dimensions; fatigue and theories of failure.

1155. *APPLIED DIFFERENTIAL EQUATIONS.* Credit 3 hrs. 1 Lect. 2 Rec. Prereq., 1151 and Mathematics 163. The formulation and solution of problems, arising in mechanical engineering, which involve the use of elementary differential equations and Fourier series. Emphasis is placed on numerical as well as analytical methods of solution.

1156. *APPLIED DIFFERENTIAL EQUATIONS.* Credit 3 hrs. 1 Lect. 2 Rec. Prereq., Mathematics 163. The formulation and solution of problems in chemical engineering involving ordinary and partial differential equations, graphical and numerical methods, and special functions.

1159. *ADVANCED MECHANICS LABORATORY.* Credit 3 hrs. 2–2½ hour Lab. Fall or spring as announced. Primarily for graduate students. Analysis and design of experiments; measuring and loading techniques; SR-4 strain gages; vibration analysis of rods, plates, and shells.

1162. *MECHANICS OF VIBRATION.* Credit 3 hrs. 3 Lect. Fall or spring as announced. For graduates and qualified undergraduates. Vibration of lumped and continuous systems; dampening; free and forced motion; resonance; vibration isolation; self-excited vibration.

1163, 1164. *APPLIED ELASTICITY.* Continuing two terms. Credit 3 hrs. 3 Lect. For graduates and qualified undergraduates; spring and fall terms respectively. Three lectures per week each term. General analysis of stress and strain; Airey's stress function; Fourier and strain energy methods; torsion; thick cylinders; disks; beams on elastic foundations; curved bars; Castigliano's theorem.

Kimball Hall (left) and Thurston Hall, built in 1951, house materials processing and testing facilities for the several divisions of the College.

1165. *MATHEMATICAL ELASTICITY.* Credit 3 hrs. 3 Lect. Spring term. Prereq., 1163, 1164. Graduate students. Mathematical theory of elasticity using tensor development; plates and shells; finite deformation; complex variable techniques—Muskhelishvili's method.

1166. *STRESS WAVES IN SOLIDS.* Credit 3 hrs. 3 Rec. Prereq., 1162, 1163 or equivalent. Graduate students.

Equations of elasticity; vibrations and waves; the propagation of waves in elastic media; waves in elastic half-space; waves and vibrations in elastic plates and rods; waves in visco-elastic solids; plastic waves.

1167. *PLATES AND SHELLS.* Credit 3 hrs. Graduate students. Differential equation of plates in cylindrical coordinates and use in various cases of axial symmetrical and unsymmetrical loading and boundary conditions, including flat slabs. Use of cartesian coordinates for rectangular plates with various boundary conditions, flat slabs, etc. Numerical methods. Membrane theory of axial symmetrical shells under axial symmetrical and unsymmetrical loading and application to practical cases. Bending theory of axial symmetrical shells. Bending theory of cylindrical shells under unsymmetrical loading with application to engineering practice.

1168. *PLASTICITY AND STABILITY.* Credit 3 hrs. Graduate students. Plastic behavior as based on crystalline structure. Brittle vs. plastic behavior. Mechanism of plastic deformation and plasticity condition. Local plastic deformations. Application to structures and geophysics. Stress-strain relations for plastic buckling of plates and shells. Tubes under internal and external pressure. Other cases of plain strain. Slip lines. Elastic and plastic buckling of columns, plates and shells. Haarman method. Method of split rigidities. Postbuckling behavior.

1170. *ADVANCED MECHANICS.* Credit 3 hrs. Fall term. 3 Rec. Prereq., 1180, 1181, or permission of the instructor. The formulation and solution of problems in engineering by vector methods. Lagrange's equations, generalized coordinates, Fourier series. Conservative systems.

1172. *SELECTED TOPICS IN ENGINEERING MECHANICS.* Credit as arranged, any term. Qualified students wishing to do work in any field of engineering mechanics should register for this course after consultation with the Department. Students will work with appropriate members of the staff in the chosen field. Typical areas of work include theory of elastic stability, theory of plates and shells, rocket theory and design, and wave propagation.

1173. *RESEARCH IN APPLIED MECHANICS.* Credit to be arranged. Thesis or independent research in a field of applied mechanics. Such research must be under the guidance of a staff member.

1175. *INTRODUCTION TO NONLINEAR MECHANICS.* Credit 3 hrs. 3 Rec. Spring term. A study of the methods of analysis of the nonlinear electrical and mechanical systems frequently encountered in practice, including criteria for stability and a comparison between linear and nonlinear methods.

1180. *ADVANCED ENGINEERING MATHEMATICS.* Credit 3 hrs. Fall term. 3 Lect. Prereq., 1155 or equivalent. Linear differential equations, Laplace transforms, infinite series, transcendental equations, orthogonal functions, calculus of variations, partial differential equations. Special applications in mechanical and civil engineering and mechanics.

1181. *ADVANCED ENGINEERING MATHEMATICS.* Credit 3 hrs. Prereq., 1180. Applications to engineering problems of vector analysis, functions of a complex variable, matrices and linear equations, difference equations and integral equations.

1198, 1199. *PROJECT.* Credit 3 hrs. each term. Work of the ninth and tenth terms

in the form of projects to integrate the training in mechanical engineering when such work is done principally in the field of engineering mechanics.

1201. *ENGINEERING MATERIALS.* Credit 4 hrs. 3 Lect. 1 Lab. Prereq., 1153 and Chemistry 402. A lecture course treating the physical and electrical properties of engineering materials with special emphasis on the relation of these properties to the structure of the materials and to their forming, working, heat treatment, etc.

1202. *ADVANCED ENGINEERING MATERIALS.* Credit 3 hrs. Fall term. Primarily for fifth year students in engineering physics; others with consent of instructor. Discussion of a number of special topics in the field of engineering materials, such as plastic and rheological properties; dielectric and magnetic behavior; semi-conductors, etc. Emphasis is given to the interpretation of the phenomena in light of modern theories in physics of solids and liquids; current literature is included in the assignments. (See Engineering Physics.)

1212. *ENGINEERING MATERIALS.* Credit 3 hrs. 1 Lect. 2 Lab. Prereq., 1241. Should be preceded by or taken concurrently with 2715. Timber, cement, concrete aggregates, concrete, elemental concrete structural members, lime, gypsum. Design of concrete mixes, acceptability of materials, and physico-chemical properties of materials. Extensive laboratory testing and report writing.

1216. *STRUCTURE AND PROPERTIES OF MATTER.* Credit 2 hrs. Fall term. 2 Lect. Open to graduate students in engineering or the physical sciences or by consent of instructor. Internal structure of materials ranging from the amorphous to the crystalline state. Correlation of the internal structures of materials with their physical and mechanical properties, primarily on a qualitative basis. Applications to metals and other engineering materials.

1217. *ADVANCED PLAIN CONCRETE.* Credit 2 hrs. Spring term. 2 Lect. Prereq., 1212 or the equivalent. Topics in the field of concrete, such as history of cementing materials, air-entrainment, light-weight aggregates, petrography, durability, chemical reactions and properties of aggregates. Relationships between internal structure, physical properties, chemical properties, and the mechanical properties of interest to the design and construction engineer.

1241. *ENGINEERING MATERIALS.* Credit 3 hrs. 2 Lect. 1 Lab. Prereq., 1153, and Chem. 401 or 402. An introductory lecture-laboratory course. Structure and mechanical properties of metals and alloys. Ferrous metals: carbon steels, cast irons, alloy steels. Nonferrous metals. Wood, plastics, cements, and concrete.

1242. *ENGINEERING MATERIALS.* Credit 3 hrs. 2 Lect. 1 Rec. Prereq., 1241. A lecture course making a detailed study of the fundamentaal structure and mechanical properties of metals and alloys and the effects of hot and cold working. Carbon and low alloy steels in the annealed and heat treated condition. High alloy steels.

1243. *ENGINEERING MATERIALS.* Credit 3 hrs. 1 Lect. 1 Rec. 1 Lab. Prereq., 1242. A lecture-laboratory study of the structure and properties of cast irons, nonferrous metals and alloys, special purpose alloys. Corrosion. Nonmetallic materials: plastics, glass, rubber, lubricants.

1244. *THEORETICAL MATERIALS—MECHANICAL PROPERTIES.* Prereq., 1243 or instructor's permission. Credit 3 hrs.

A discussion of the structure-sensitive mechanical properties of materials attributable to imperfections in crystals. This includes the role of dislocations, impurities, vacancies, and interstitial atoms and their effect on such properties as plastic flow, fatigue, creep, and fracture.

1252. *APPLICATIONS OF ENGINEERING MATERIALS.* Credit 3 hrs. 2 Lect. 1 Rec. Prereq., 1243. The applications of physical metallurgy to problems in engi-

neering and processing operations, including casting, mechanical working and heat treatment, and the use of ferrous and nonferrous metals and alloys.

1255, 1256. *MATERIALS OF CONSTRUCTION.* Credit 3 hrs. each term. 3 Lect. Prereq. or parallel courses, Physical Chemistry 403, 404. An introductory presentation of the nature, properties, treatment, and applications of the more important metals and alloys, including extractive and physical metallurgy and behavior under service conditions. Nonmetallic materials, including refractories, cement, protective coatings, and plastics, are also discussed.

1273. *RESEARCH IN ENGINEERING MATERIALS.* Credit to be arranged. Thesis or independent research in a field of applied mechanics. Such research must be under the guidance of a staff member.

1298, 1299. *PROJECT.* Credit 3 hrs. each term. Work of the ninth and tenth terms in the form of projects to integrate the training in mechanical engineering when such work is done principally in the field of engineering materials.

CIVIL ENGINEERING

DESCRIPTIVE GEOMETRY AND DRAWING

Mr. Hewitt and others.

2001. *DESCRIPTIVE GEOMETRY AND DESIGN.* Credit 3 hrs. Fall. Orthographic projection, auxiliary projections, and basic descriptive geometry provide a thorough coverage of the theory of drawing. Technical lettering, the use of instruments, and freehand sketching are stressed in the preparation of general civil engineering designs where the student is given the opportunity to use his creative imagination in original design. Dimensioning practice and sectional views are presented concurrently with the preparation of design plans.

2002. *GRAPHICS AND DESIGN.* Credit 3 hrs. Spring. Prereq., 2001 or equivalent. Topics included are intersections and developments, pictorial projection, perspective, charts and graphs, vector diagrams, nomographs, and piping and welding representations. Architectural, topographic, and structural drawing practices are developed through original designs.

The Drawing 2001–2002 sequence completely covers the fundamentals of engineering drawing, descriptive geometry, graphical solutions, and civil engineering drafting practices. Use is made of a number of educational films as visual aids to instruction.

2004. *ADVANCED DRAWING.* Credit 1–3 hrs. Problems in concrete, structural, topographical, highway, and sanitary drafting; engineering drawings, rendered in color, to enable the student to supplement ordinary drawings with artistic representations, so portrayed as to be readily intelligible to persons without technical training.

2005. *CARTOGRAPHY.* Credit 3 hrs. Fall. A study of the field of cartography, with particular attention to the principles of map projections, the conventions, scales, and construction of planimetric topographic, and chorographic maps from survey notes and data from aerial photographs. A first course to combine photogrammetry and topographic surveying into a practical course on map making and interpretation.

2006. *MAP REPRODUCTION.* Credit 3 hrs. Spring. The preparation of map manuscripts and models for reproduction by both photographic and mechanical methods of duplication. The selection, evaluation, and organization of cartographic material from ground and aerial surveys into map editions will assure the proper procedure to adopt for local circumstances.

Scheduled for occupancy in September, 1959, Hollister Hall will be dedicated to the School of Civil Engineering.

SURVEYING

Messrs. Anderson, Lyon, McNair, Moore, and others.

2111. *ELEMENTARY SURVEYING.* Credit 2 hrs. Spring. 1 Rec. 1 Lab. Use and care of steel tape, level, and transit; note keeping; fundamental surveying methods; measurements of lines, angles, and differences of elevations; areas and plotting.

2112. *ADVANCED SURVEYING.* Credit 3 hrs. Spring. 2 Rec. 1 Lab. Prereq., 2111. Elements of topographic, hydrographic, and geodetic surveying; map projections; elements of practical astronomy; city, land, and mine surveying; theory of errors; surveying specifications.

2113. *ROUTE AND AERIAL SURVEYING.* Credit 3 hrs. Fall. 1 Rec. 2 Lab. Prereq., 2111. Theory and applications of photogrammetric methods; theory and practice in staking out route locations involving simple, transition, and vertical curves; earthwork measurements and computations. About one third of the course is devoted to photogrammetry, one third to paper reconnaissance, curve theory, and earthwork computations, and one third to field work associated with route locations.

2114. *SUMMER SURVEY.* (Topographic, Hydrographic, Route, and Geodetic Survey Camp.) Credit 5 hrs. Field and office work six days a week for five weeks. Date to be announced in spring term. Prereq., 2112 and 2113. Design and execution of topographic survey and corresponding map with emphasis on transit-stadia and plane table-stadia methods; hydrographic survey and map of Cayuta Lake; and complete route survey including reconnaissance from aerial photographs, preliminary survey, paper location, and staking of the final line. All horizontal and vertical control surveys are executed according to present standards for base-line taping, triangulation with repeating and direction type optical-reading theodolites, subtense and trig traverse, precise leveling, and altimetry. Astronomic observations for azimuth and position are made and results computed.

2115. *ADVANCED ENGINEERING MEASUREMENTS.* Credit 3 hrs. Fall term. Prerequisites: laboratory work involving Physical Measurements, Math. 163, and permission of the instructor.

Measurement systems; analysis of errors and of error propagation; application of the principles of probability to the results of measurements for the purpose of determining the best estimates of measured and deduced quantities, and the best estimate of uncertainty in these quantities; adjustment of conditioned measurements by the method of least squares and other methods; curve fitting; and data processing methods.

2116. *LAND SURVEYING.* Credit 3 hrs. 3 Rec. Prereq., permission of the instructor. Functions and responsibilities of a land surveyor; deeds and land descriptions; land records and land courts. Study of U. S. public land system, metes and bounds, subdivisions, resurveys, cadastral surveys, riparian rights, mineral land surveys, and other land survey systems. Specifications and registration.

2117. *GEODETIC SURVEYING.* Credit 3 hrs. 3 Rec. Prereq., permission of the instructor. Consideration of special problems in geodetic surveying; base line; triangulation; traverse; precise leveling; deflection of the plumb line; figure of the earth; determination of gravity; isostasy; magnetic properties of the earth. Subject to arrangement to meet the special needs of students.

2119. *MAP PROJECTIONS.* Credit 3 hrs. The theory of map projections. Construction of projections. Plane coordinate systems.

2120. *VERTICAL CONTROL.* Credit 3 hrs. Prereq., 2112. Lectures, reading, and field work. Principles of establishing a geodetic sea-level datum and of performing barometric, trigonometric, spirit, and electronic leveling. Study of precision altimetry

by the single-base, two-base, and leapfrog methods. Determination of economic relationships of vertical control methods to mapping scale especially for photogrammetric mapping.

2121. *ELEMENTS OF PHOTOGRAMMETRY.* Credit 3 hrs. Fall. Prereq., 2113. Lectures, recitation, and laboratory work. Principles and practice of terrestrial and aerial photogrammetric mapping, including planning flights, control surveys, uncontrolled mosaics, radial-line control, simple stereo-plotting instruments, parallax distortions, graphical tilt determination, trimetrogen charting, and economics.

2122. *ADVANCED PHOTOGRAMMETRY.* Credit 3 hrs. Spring. Prereq., 2121 or permission of the instructor. Lectures, reading, and laboratory work. An advanced study of photogrammetric principles including controlled mosaics, rectification, graphical, mechanical, and analytical space orientation. Readings and reports from current technical literature. The principles of many photogrammetric plotters are studied together with the economic relation of these instruments to density of field control, office methods, and personnel.

2123. *SURVEYING AND MAPPING INSTRUMENTATION.* Credit 3 hrs. Prereq., 2121. Lectures and assigned reading. Independent study of developments in surveying, mapping, and photogrammetric instruments including a brief historical sketch of instrumentation; optical-reading levels and transits; electronic base line measurement; precision altimeters; sonar equipment; equiangulator, odograph, and stereoscopic plotters. Correlation of the principles of physics and mathematics in new measuring instruments and methods.

2131. *ELEMENTS OF SURVEYING.* Credit 1 hr. 1 Lab. Fundamentals of engineering measurements. Appreciation of observations and errors. Principles of recording data. Use of steel tape, level, and transit. Optical tooling. Problems of particular interest to students in fields other than civil engineering.

2132. *SURVEYING.* Credit 3 hrs. Spring. 2 Rec. 1 Lab. Fundamentals of engineering measurements. Appreciation of methods of observations and errors. Principles of recording data. Use of steel tape, level, transit, and plane table. Aerial mapping. Emphasis on problems common in agricultural engineering.

2142. *GEODETIC OR PHOTOGRAMMETRIC ENGINEERING RESEARCH.* Prerequisites will depend upon the area of studies to be pursued. Special problems in error analysis, geodesy, and photogrammetry as may be arranged.

2143. *SEMINAR IN GEODESY OR PHOTOGRAMMETRY.* Credit 1–6 hrs. Open to specially selected seniors or graduate students. Abstraction and discussion of technical papers and publications in the geodetic or photogrammetric field.

HYDRAULICS AND HYDRAULIC ENGINEERING

Messrs. Bogema and staff.

2301. *FLUID MECHANICS.* Credit 3 hrs. 3 Rec. Prereq., 1152. Fluid properties. Pressure and pressure intensity. Hydrostatics. Fluid flow concepts and basic equations. Dimensional analysis. Similitude. Laminar and turbulent flow. Flow in pipes. Flow around immersed bodies.

2302. *APPLIED HYDRAULICS AND HYDROLOGY.* Credit 3 hrs. 2 Rec. 1 Lab. Prereq., 2301. Application of fluid mechanics principles to hydraulic problems. Flow in open channels. Flow measurement. Hydraulic machinery. Elements of hydrology.

2303. *ADVANCED HYDRAULICS.* Credit 3 hrs. Fall. 3 Rec. Prereq., 2302 or 2331. More detailed and extended theory and application than the first course. Problems

considered include stability of flotation, barometric leveling, fluids subject to acceleration, hydraulic similitude, water hammer, and pipe flow.

2304. *HYDRAULIC MEASUREMENTS.* Credit 3 hrs. Fall. 2 Rec. 1 Lab. Prereq., 2302. The general flow equation. Volumetric and weight measurements. Pressure and pressure intensity. Measurements of fluid velocity. Rate of flow measurements in pipelines and open channels. Measurements under special conditions. Graphical and analytical methods of analyzing data. Errors and tolerances.

2305. *HYDRODYNAMICS.* Credit 3 hrs. Spring. 3 Lect. Prereq., 2302 or 2331 and differential equations. Equations of motion for nonviscous liquids, force potentials, velocity potentials, conformal mapping, circulation, vortices, equations of motion for viscous liquids, boundary layer, separation, drag, turbulence, and wave motion.

2306. *PUMPS AND TURBINES.* Credit 3 hrs. Spring. 2 Rec. 1 Lab. Prereq., 2302 or 2331. Theory and characteristics of the hydraulic ram; reciprocating and centrifugal pumps; impulse, reaction, and propellor type turbines; selection and testing of hydraulic machinery.

2307. *FLOW OF LIQUIDS IN OPEN CHANNELS.* Credit 3 hrs. Fall. 3 Lect. Prereq., 2302. Uniform flow, gradually varied flow, rapidly varied flow, subcritical transitions, waves, supercritical transitions, bends, precipitous slopes, energy dissipation, and spillways.

2308. *HYDRAULIC MODELS.* Credit 3 hrs. Spring. 1 Rec. 2 Lab. Prereq., 2302. Theory of similitude and its application to models. Dimensional analysis, development of prediction equations, observations and measurements, theory of models, design and construction of models, distorted models, models of rivers, spillways, and outlet works.

2331. *FLUID MECHANICS.* Credit 3 hrs. 3 Rec. Prereq., 1152. Statics, dynamics of fluid flow, law of continuity, energy equation, turbulence, flow of compressible fluids, impulse momentum relations, resistance of submerged bodies, lubrication, and hydraulic machinery.

2342. *HYDRAULICS RESEARCH.* Prereq., 2302 or the equivalent. Credit 1–6 hrs. The subject and scope of the investigations in experimental or theoretical hydraulics should be selected by conference at the beginning of the term if not previously arranged. It is permissible and often desirable for two students to work together on the same investigation.

2343. *HYDRAULICS SEMINAR.* Credit 1 hr. Abstraction and discussion of technical papers and publications in the field of hydraulics.

2403. *HYDRAULIC STRUCTURES.* Credit 3 hrs. Spring. 3 Rec. Prereq., 2412. Discussion of advanced problems related to hydraulic structures. Stress analysis in dams. Design of arch dams. Spillways and river protection works. Channel transitions and controls. Hydraulics of locks.

2404. *WATER POWER.* Credit 3 hrs. Fall. 2 Lect. 1 Comp. Prereq., 2302. Hydrologic and hydraulic investigation of water power sites; selection of turbines, power plant layout and equipment; economic considerations. Problems cover determination of available power, selection of turbines, use of pondage and storage, and determination of annual power output.

2411. *RIVERS AND HARBORS.* Credit 3 hrs. Fall. 3 Lect. Prereq., 2302 and 2412. Rivers: regimen of flow in natural streams, flood waves, flood control, sedimentation, channel improvement, canalization, tidal effects, and ports. Harbors: gravity waves, shore improvement, harbor improvement, ports, and canals.

2412. *HYDRAULIC ENGINEERING.* Credit 3 hrs. 3 Rec. Prereq., 2302. Introduction to hydraulic engineering problems. Purpose, planning, and component parts

of hydraulic projects. Flood routing, sedimentation. Ground water hydraulics. Reservoirs. Dams, spillways, and river protection works. Flumes and channels. Conduits, tunnels, penstocks. Locks. Hydraulic model studies.

2442. *HYDRAULIC ENGINEERING RESEARCH.* Prereq., 2412 and one additional elective course in field of selected research. Subject and scope of investigation to be undertaken is selected by conference at beginning of term. Extraction of pertinent data from all available sources, construction and operation of hydraulic laboratory models.

2443. *HYDRAULIC ENGINEERING SEMINAR.* Credit 1 hr. Discussion of selected topics in the hydraulic engineering field.

SANITARY ENGINEERING

Messrs. Gates, Lynch, Morancie, and Naismith.

2501. *MICROBIOLOGY IN ENGINEERING.* Credit 3 hrs. 2 Lect.-Rec. 1 Lab. Prereq., Chemistry 106. Introduction to the nature, characteristics, and activities of microorganisms and their effects on man and his environment, emphasizing their role in the aerobic and the anaerobic decomposition of organic substances, the deterioration of engineering materials, and the transmission of disease. The application of these principles and phenomena to civil engineering.

2502. *WATER SUPPLY AND SEWERAGE SYSTEMS.* Credit 3 hrs. 2 Lect.-Rec. 1 Comp. Prereq., 2301. Introduction to the function and design of structures and appurtenances for (1) the collection, conveyance, and distribution of water for municipal use, (2) the collection and transportation of municipal wastes and storm water. Computation periods include individual reports on design problems.

2503. *WATER AND WASTES TREATMENT.* Credit 3 hrs. 2 Lect.-Rec. 1 Comp. or Lab. Prereq., 2301, 2501, 2502. Study of water and waste treatment processes in terms of the underlying physical, chemical, and biological principles; the application of these principles to the function and design of unit treatment processes and of integrated treatment plants. The influence of the natural purification of streams on waste treatment and waste disposal.

2504. *SANITARY BIOLOGY AND STREAM SANITATION.* Required of graduate students who have not had 2501 or its equivalent. Credit 3 hrs. 2 Lect.-Discuss. 1 Lab. Either term. Fundamentals and methods of microbiology and their application to the bacteriology and biology of water and waste treatment processes, and to the natural purification of pulluted waters. Methods for estimating and evaluating the capacities of streams to assimilate wastes.

2506. *ADVANCED WATER SUPPLY.* Credit 3 hrs. Spring. Prereq., 2503. Lectures, problems, reports, and field trips. Advanced study of the theory of water treatment processes and of water supply methods, and their application to the design of municipal and industrial water treatment plants; water quality standards and control methods.

2507. *ADVANCED WASTES TREATMENT.* Credit 3 hrs. Fall. Prereq., 2503. Lectures, problems, reports, and field trips. Advanced study of the theory of waste treatment processes; the design of treatment units and treatment plants; waste disposal and water pollution control methods. Study of current literature.

2508. *INDUSTRIAL AND NUCLEAR WASTES.* Credit 3 hrs. Prereq., 2503. Basic industrial waste treatment processes and disposal methods. Specific industrial waste problems and treatment processes. Nature, treatment, and disposal of nuclear reactor and other radioactive wastes.

2509. *PUBLIC HEALTH AND ENVIRONMENTAL SANITATION.* Credit 3 hrs. Spring. Lecture-discussions, reports, and field trips. An introduction to public health principles and practice, including the nature and activities of local, state, and national public health organizations. Environmental sanitation, emphasizing municipal and individual water supply and waste disposal methods, air and food sanitation.

2510. *SANITARY CHEMISTRY.* Credit 3 hrs. 2 Lect.-Discuss. 1 Lab. Prereq., 1 year of college chemistry. Primarily intended for graduate students and upperclassmen especially interested in sanitary engineering. Fundamentals of analytical, physical, and organic chemistry specifically applicable to the design and control of water and waste treatment processes.

2511. *SANITARY ENGINEERING LABORATORY.* Credit 3 hrs. 1 Lect.-Discuss. 2 Labs. Prereq., 2510 or parallel registration; 2503. Laboratory studies of water and waste treatment processes, including the application of physical, chemical, and biological principles, methods, and procedures to the treatment of water, sewage, and industrial wastes.

2532. *MUNICIPAL SANITATION.* For non-civil engineering students. Credit 3 hrs. Fall. Lecture-discussions, reports, and field trips. Water supply, municipal and individual sewage and solid waste disposal and air sanitation methods as they relate to municipal and regional planning, development, and management. Water and air pollution control programs.

2541. *PROJECT, SANITARY ENGINEERING.* Credit 3 hrs. Prereq., 2502 and 2503 or equivalent courses. Students will elect or be assigned individual or group design problems dealing with sewerage systems, water supply, or water distribution systems; water treatment plants; municipal waste treatment and industrial waste treatment plants.

2542. *SANITARY ENGINEERING RESEARCH.* Prerequisites will depend upon the particular problem to be pursued, but in general they should include water analysis and those courses in hydraulics and sanitary engineering pertinent to the field in which the study is to be undertaken. Hours and credit variable.

2543. *SANITARY ENGINEERING SEMINAR.* Open to interested upperclassmen and graduate students. Credit 1–6 hrs. Presentation and discussion of technical papers and publications in the sanitary engineering field.

TRANSPORTATION ENGINEERING

Messrs. Belcher, Lewis, and Liang.

2602. *TRANSPORTATION.* Credit 3 hrs. 3 Rec. Prereq., Economics 103 or permission of the instructor. The historical, economic, regulatory, construction, and operational aspects of transportation. Designed particularly for engineering students.

2610. *HIGHWAY ENGINEERING.* Credit 3 hrs. 2 Lect. 1 Lab. Prereq., 2113, and preceded by or taken concurrently with 2725. Highway administration, planning, economy, and finance; location (aerial photo methods included); elements of geometric design, intersections; traffic engineering; drainage; highway materials and soils; subgrade; base courses; design and construction of flexible and rigid pavements.

2612. *HIGHWAY LABORATORY—BITUMINOUS.* Credit 3 hrs. Fall. 2 Labs. 1 Seminar. Prereq., 2610, or may be taken concurrently with 2610. Bituminous materials are tested and aggregates studied for their compatibility with bitumens. Mixes are designed and tested. Condition surveys are made on various classes of bituminous pavements. Laboratory fully equipped for all phases of applied and research studies.

2613. *HIGHWAY LABORATORY—SUBGRADE SOILS.* Credit 3 hrs. Spring. 2 Labs. 1 Seminar. Prereq., 2725 and 2610, or may be taken concurrently with 2610. Evaluation of current soil engineering practices. Soil surveying and sampling. Correlation of field and laboratory compaction procedures. Freeze-thaw and strength tests on soil samples stabilized with bituminous materials, Portland cement, and chemicals. Condition surveys are made on stabilized roads. Laboratory fully equipped for all phases of applied and research studies.

2614. *HIGHWAY DESIGN—STRUCTURAL.* Credit 3 hrs. Fall. 3 Rec. Prereq., 2610 or permission of the instructor. Part I: Soil index properties and highway soil classification systems; surveying and sampling; subgrade evaluation, including field and laboratory CBR; subgrade modulus; compaction, drainage, and frost action; stabilization; aggregates. Part II: Design and construction of base and surface courses for flexible pavements. Part III: Design and construction of rigid pavements.

2615. *HIGHWAY DESIGN—GEOMETRIC.* Credit 3 hrs. Spring. 1 Lect. 2 Lab. Prereq., 2610 or permission of the instructor. Route selection; design controls and criteria, including vehicle characteristics and highway capacity; sight distance, and horizontal and vertical control; cross section elements; right-of-way problems and access control; at-grade intersection design, including rotary and channelized intersection; grade separations and interchanges; regional systems of highways, freeways, and parkways.

2617. *AIRPORT ENGINEERING.* Credit 3 hrs. Spring. 2 Rec. and 1 Lab. Prereq., 2610, 2725. Airport administration, planning, and design. Site selection—size and location; design standards; airport layout—runway patterns and orientation; flexible and rigid pavement design; drainage, gradings; marking, lighting; heliports.

2618. *LOW-COST ROADS.* Primarily for foreign students. Credit 3 hrs. Prereq., 2610 or the equivalent. Study of economic importance of routes and selection of roads to be improved; location and design; subgrade soils and stabilization of subgrade soils by use of admixtures, chemicals, and bituminous materials; drainage structures; bituminous treatments and bituminous mats for stabilized subgrades. Survey of the experimental work in the use of materials and design and construction of low-cost roads.

2619. *TRAFFIC ENGINEERING—OPERATIONS.* Credit 3 hrs. 2 Lab. 1 Seminar. Prereq., preceded by or taken concurrently with 2620. Definition of traffic problems; collection of field data; analysis of field data; findings, conclusions, and recommendations. Traffic surveys. Design of traffic control systems.

2620. *TRAFFIC ENGINEERING.* Credit 3 hrs. 2 Rec. 1 Lab. Prereq., 2610 or permission of the instructor. City and highway traffic surveys and designs. Accidents, congestion, delay, speed, volume, density, parking, channelization, lighting, traffic control and routing. Signs, signals, and markings. Urban traffic consideration in city planning. Driver reactions and habit pattern. Traffic engineering organization.

2621. *ANALYSIS AND INTERPRETATION OF AERIAL PHOTOGRAPHS.* Preregistration required. Credit 3 hrs. 2 Lect. 1 Lab. (The student is expected to pay the cost of field trips and aerial photographs for use in a term project, amounting to approximately $15.) A study of the soil and rock areas of the United States and the patterns present in aerial photographs. Fundamental elements of soil patterns are analyzed to permit determination of soil texture, type of bedrock, and drainage properties. Field training in selected test areas. Emphasis is placed on interpretation for engineering, regional planning, and agricultural purposes.

2622. *ADVANCED INTERPRETATION OF AERIAL PHOTOGRAPHS.* Preregistration required. Credit 3 hrs. Organization of course depends upon fields of interest. Special problems: four each on ground water, engineering projects, agricultural soils mapping, irrigation, and geology.

2641. *PROJECT, TRANSPORTATION ENGINEERING.* Credit 3 hrs. Projects in the various fields of transportation, advanced aerial photographic studies, and traffic engineering may be developed by conference between professors and students. Projects may involve integrated planning or design drawing upon several fields of interest, or they may concentrate upon special subjects. Adequate facilities, material, and sources of data are necessary to a satisfactory project.

2642. *TRANSPORTATION ENGINEERING RESEARCH.* Students who wish to pursue one particular branch of transportation engineering further than can be done in any of the regular courses may elect work in this field. The work may be in the nature of an investigation of existing methods or systems, theoretical work with a view to simplifying present methods of design or proposing new methods, or experimental investigation of suitable problems.

2643. *TRANSPORTATION ENGINEERING SEMINAR.* Credit 1–2 hrs. Number of meetings a week to be arranged. Abstraction and discussion of selected technical papers and publications in the transportation engineering field.

STRUCTURAL ENGINEERING

Messrs. Fisher, Mason, McGuire, Nilson, Sturman, and Winter.

2701. *ELEMENTARY STRUCTURAL ANALYSIS.* Credit 3 hrs. 2 Lect. 1 Lab. Prereq., 1153. A first course in structural theory. Determination of reactions and internal forces and moments in beams, girders, trusses, simple frames, and three-hinged arches due to stationary and moving loads. Use is made of graphical and analytical methods and of influence lines.

2702. *STEEL AND TIMBER STRUCTURES.* Credit 3 hrs. 3 Lab. Prereq., 2701, 1134. Analysis and design of steel members and connections. Design of welded roof truss. Design of mill-type steel building, including riveted roof trusses, crane girders, crane and building columns, bracing system. Elements of timber design.

2704. *STATICALLY INDETERMINATE STRUCTURES.* Credit 3 hrs. 3 Lect. Prereq., 2702. Deflections. Classical and modern methods of analysis of statically indeterminate beams, frames, trusses. Influence lines.

2706, 2707. *ADVANCED STEEL DESIGN.* Spring and fall term sequence. Credit 3 hrs. per term. 3 Rec. Prereq. 2710; 2708 prereq. for 2707. Bridge types and economy. Design of a highway truss bridge. Elastic and plastic designs of a rigid frame building. Partial design of tier building frame including wind and earthquake effects. Other dynamically loaded structures. Design of a steel plate structure. Suspension roof systems. Continuous composite bridges. Design of light-weight alloy structural elements. Critical review of current specifications, design, and fabrication procedures throughout.

2708, 2709. *ADVANCED STRUCTURAL ANALYSIS.* Credit 3 hrs. a term. 3 Lect. a week throughout the year, fall-spring. Prereq. 2704 or equivalent. Review of fundamental methods for analyzing indeterminate structures and extension to complex structural systems. Arches, curved beams, out-of-plane loading, suspension structures, trussed and rigid space frames, etc. Mechanical model analysis, numerical methods, matrix solution of structures, use of digital computers in analysis and design.

2710. *STRENGTH OF STRUCTURES.* Credit 3 hrs. 3 Rec. Prereq., 2704; can be taken concurrently. Analysis of two- and three-dimensional stress and strain. Theories of failure of ductile and brittle materials. Strain energy methods applied to bending, shear, buckling, and impact. Structural materials under load, strain hardening, residual stresses, hysteresis, stress concentration, alternating stress. Design for fatigue. Stresses beyond the elastic limit. Inelastic behavior of steel and reinforced concrete structures. Critical discussion of current design specifications.

2711. *BUCKLING OF STRUCTURES.* Credit 3 hrs. Prereq., 2710 and 1145 or the equivalent. Analysis of elastic and plastic stability. Determination of buckling loads and maximum stresses of columns with and without eccentricity. Solid and open web columns with variable cross-section. Beam columns. Frame buckling. Lateral strength of unbraced beams. Buckling loads and ultimate strength of thin plates. Critical discussion of current design specification.

2713. *STRUCTURAL DESIGN.* Credit 3 hrs. 3 Lab. Prereq., 2702, 2704, 2715, 2720. Primarily a project course. Discussion of fatigue, limit design, light gage steel design. Design of a highway truss bridge. Planning and design of representative portions of a complete structural project (building, bridge, or other structure selected by student). Integrated use of procedures presented in other courses.

2715. *REINFORCED CONCRETE DESIGN.* Credit 3 hrs. 3 Lab. Prereq., 2704; can be taken concurrently. A first course in reinforced concrete. Elementary theory of reinforced concrete applied to rectangular beams, one- and two-way slabs, T-beams, beams reinforced for compression, concentric and eccentric columns. Shear and bond. Introduction to ultimate strength theory. Design project comprising partial design of concrete building frame.

2716, 2717. *CONCRETE STRUCTURES, REINFORCED AND PRESTRESSED.* Credit 3 hrs. Spring, fall. Prereq., 2704, 2715, 2708 (for 2717). Review of member design. Ultimate strength theory. Flat-slab and flat-plate design, including bent analysis. Yield line theory. Framing systems in current use. Prestressed concrete. Folded plate construction. Membrane analysis of domes and hyperbolic paraboloids. Critical discussion of current design specifications.

2720. *FOUNDATIONS.* Credit 3 hrs. 2 Lect. 1 Lab. Prereq., 2715, 2725. Study of the structural problems encountered in foundation work. Retaining walls, sheet piling, spread footings, piles, piers, abutments, cofferdams, caissons, underpinnings. Design problems.

2725. *ELEMENTS OF SOILS ENGINEERING.* Credit 3 hrs.. 2 Lect. 1 Lab. Prereq., Geology 113, Eng. 1153, 2301. Formation and composition of soil, its properties and its behavior as an engineering material. Principles of soil identification and classification, terminology and soil characteristics such as gradation, permeability, compressibility, consolidation, and shearing strength with application to simple problems of seepage, settlement, bearing capacity, stability of earth slopes. Lateral earth pressure. Soil exploration. Laboratory tests for experimental determination of above mentioned soil characteristics and evaluations and use of data.

2726. *SOILS ENGINEERING THEORY.* Credit 3 hrs. Fall. 3 Lect. Prereq., 2725. Principles of mechanics and strength of materials relating to typical soils engineering problems and the fundamental physical and chemical characteristics of soil which affect their application. Methods for determining the distribution of stresses in semi-infinite soil masses, stress at a point, and the Mohr theory of rupture. Composition, structure, and stress-strain characteristics of soil. Calculation of settlement of structures, the stability of earth slopes and of embankment foundations. Basic principles of flow of water through soil, flow net construction, rate and effect of seepage. Lateral earth pressure theory.

2727. *APPLIED SOILS ENGINEERING.* Credit 3 hrs. Spring. 2 Lect. 1 Lab. Prereq., 2726. Application of soils engineering theory of problems. Planning and conducting of subsurface investigations, determination of significant physical and chemical soil characteristics by test or other means, including appropriate laboratory exercises, analysis of actual designs of proposed structures for prediction of settlement, stability, rate of seepage, or other service requirements, methods of inspection and control of earthworks construction, selection and placement of materials, compaction and stabilization.

2731. *ELEMENTS OF STRUCTURAL ENGINEERING I.* Credit 3 hrs. 2 Lect. 1 Lab. Prereq., 1151, 1153. Analysis of statically determinate and simple statically indeterminate structures. Determination by means of analytical and graphical methods, of reactions and internal forces and moments caused by stationary loads. Influence lines for beams.

2732. *ELEMENTS OF STRUCTURAL ENGINEERING II.* Credit 3 hrs. 2 Lect. 1 Lab. Prereq., 2731. Design of simple steel and timber structures. Discussion of design in light gage steel and aluminum. Analysis and design of members and connections, roof trusses, floor systems, and other structures.

2741. *PROJECT.* Prereq., 2702, 2703, and 2715. The student may select a design problem such as the following: (a) an arch bridge, (b) a cantilever bridge, (c) a rigid frame bridge, (d) a special problem in steel or concrete building design, (e) the design of any other structure of particular interest to the student provided he has had the proper preparation for such design. The work is submitted in the form of reports. Drawings of typical details must accompany reports.

2742. *STRUCTURAL ENGINEERING RESEARCH.* Students wishing to pursue one particular branch of structural engineering further than can be done in any of the regular courses may elect work in this field. The prerequisite courses depend upon the nature of the work desired. The work may be in the nature of an investigation of existing types of construction, theoretical work with a view of simplifying present methods of design or proposing new methods, or experimental investigation of suitable problems.

2743. *STRUCTURAL ENGINEERING SEMINAR.* Credit 1–6 hrs. Open to specially selected seniors or graduate students. Preparation and presentation of topics of current interest in the field of structures for informal discussion.

2744. *SPECIAL TOPICS IN STRUCTURAL ENGINEERING.* Individually supervised study in one or more of the specialized topics of civil engineering such as tanks and bins, suspension bridges, towers or movable bridges, which are not covered in the regular courses. Independent design or research projects may also be selected.

SPECIAL AND GRADUATE COURSES

2801. *THESIS.* The thesis gives the student an opportunity to work out a special problem or to make an engineering investigation, to record the results of his work, and to obtain academic credit for such work. Registration for thesis must be approved by the professor in charge at the beginning of the semester during which the work is to be done.

NOTE: Individual courses may be arranged to suit the requirements of graduate students. They are intended to be pursued under the immediate direction of the professor in charge, the student usually being free from the restriction of the classroom and working either independently or in conjunction with others taking the same course.

CONSTRUCTION ENGINEERING AND ADMINISTRATION

Messrs. Gebhard, Richards, and Rogers.

2901. *CONSTRUCTION METHODS.* Credit 3 hrs. 3 Rec. Introduction to methods, equipment, and management principles and procedures involved in construction enterprises; nature of the construction industry and sources of information concerning it; problems and oral reports by students based on current literature; cor-

relation of money, men, materials, machines, and design details to produce economic results.

2902. *ENGINEERING LAW.* Credit 3 hrs. 3 Rec. Basic features of laws and practices relating to contracts, torts, agency, property, water rights, forms of business organizations, sales, insurance, utilities, labor, government regulation of business, negotiable instruments, workmen's compensation, liens, bankruptcy, patents, copyrights, trademarks; work of the expert witness; ethical responsibilities; professional registration; special emphasis on contract documents used in construction work.

2903. *ENGINEERING ECONOMY.* Credit 3 hrs. 3 Rec. Prereq., 2901, 3231. Principles governing the economic aspects of engineering decisions; time-value of money; economic selection of materials, equipment, and structures; depreciation; retirement and replacement studies; economic studies for public works. Techniques in estimating costs of engineering construction projects.

2904. *PUBLIC ADMINISTRATION.* Credit 3 hrs. 3 Rec. General principles of administration; aspects of federal, state, and local government of interest to engineers, planners, constructors, and administrators; problems in municipal engineering, city and regional planning, codes, legislation, personnel, finances, and other related topics. Written and oral reports required. Offered in recognition of the fact that a large percentage of civil engineers deal directly or indirectly with public services and management and that government is being called on to do more and more as our rapidly increasing population concentrates in urban areas.

2905. *VALUATION ENGINEERING.* Credit 3 hrs. 3 Rec. Prereq., 2901, 2902, 2903, 3231. Theory and practice of estimating the present worth of specific properties for utility rate making; buying and selling, eminent domain and condemnation proceedings, securities; bank loans, mortgages, insurance, uniform systems of accounting, and improving management.

2906. *ADVANCED ENGINEERING LAW.* Credit 3 hrs. 3 Rec. Prereq., 2902. An extension by the use of case material of some of the legal principles covered in 2902, particularly those which apply to construction contracts, and employer-employee relationships.

2907. *CONSTRUCTION MANAGEMENT.* Credit 3 hrs. Prereq., 2901, 2902, 2903, 3231. Planning and operation of construction projects by the civil engineer; coordinated organization and control of men, materials, and machines; scheduling, estimating, purchasing, selection, and training of employees; operation and maintenance of equipment; cost control and pay systems; accident prevention; and other topics. Special reports required.

2941. *PROJECT. ADMINISTRATIVE ENGINEERING.* Credit 3 hrs. Prereq., 2901, 2902, 2903. Development of a public or private engineering project selected by the student, involving economic analysis, planning, design, and construction procedures, with special emphasis on the legal, financial, and management aspects.

2942. *ADMINISTRATIVE ENGINEERING RESEARCH.* Credit 3 hrs. Prereq., 2901, 2902, 2903. Investigation of special problems relating to the economic, legal, financial, and management aspects of public and private engineering operations of interest to the engineer-administrator, consulting engineer and constructor.

2943. *ADMINISTRATIVE ENGINEERING SEMINAR.* Credit 1–6 hrs. Prereq., 2901, 2902, 2903. Guided study and discussions by small groups of selected students of topics which involve the legal, financial, and management aspects of civil engineering in public and private work, including discussions of current technical papers and publications.

MECHANICAL ENGINEERING

The courses in mechanical engineering are listed under the following headings: Drafting and Industrial Design, Thermal Engineering, Industrial and Engineering Administration, Machine Design, Materials Processing.

Required courses in the mechanical engineering curriculum given outside the College of Engineering are as follows (pages 135–145):
Chemistry 105, 106. General Chemistry
Chemistry 301. Introduction to Organic Chemistry
Chemistry 402. Introduction to Physical Chemistry
English 111, 112. Introductory course
Mathematics 161, 162, 163. Analytic Geometry and Calculus
Physics 121–128. Introductory Analytical Physics I, II, III, IV
Public Speaking 201.

Required courses in mechanics of engineering, strength of materials, and engineering materials are described on pp. 89–95.

GENERAL

3001. *INTRODUCTORY ENGINEERING.* Credit 1 hr. 2 Lect. An orientation to the School and to the field of mechanical engineering. A study of the slide rule, problems in engineering, plotting of data, and report writing.

3002. *INTRODUCTORY ENGINEERING.* Credit 2 hrs. 2 Lect. A continuation of Course 3001 with special emphasis on the responsibilities and opportunities that exist for mechanical engineers in industry. An introduction to modern industrial organization.

3041. *NONRESIDENT LECTURES.* Terms 9 and 10. Required. Total credit 1 hr. for both terms. Fall and spring. 1 Lect. Given by lecturers invited from industry and from certain other departments of the University for the purpose of assisting students in their approach to employment and in their transition from college to industrial life.

3051. *A.S.M.E. STUDENT BRANCH.* Credit 1 hr. Students who have completed at least two terms in the School of Mechanical Engineering are urged to become members of the Cornell Student Branch of the American Society of Mechanical Engineers. The meetings of the Society, however, are open to all. Attendance at any fourteen Student Branch meetings entitles the member to one hour elective credit; however, only one elective may be earned in this manner. Application for membership should be made in October of each year at the A.S.M.E. office, or to the Honorary Chairman of the Student Branch.

DRAFTING AND INDUSTRIAL DESIGN

Messrs. Abrahams, Baird, Cleary, and Siegfried.

3111. *DESCRIPTIVE GEOMETRY AND FREEHAND DRAWING.* Credit 3 hrs. Fall. 1 Lect. 2 Lab. Introduction to prerequisite arts and sciences of mechanical drafting and creative sketching; lettering; delineation; isometric; descriptive geometric anatomy; freehand pictorial and orthometric drawing; esthetics; introductory creative sketching.

3112. *BASIC MECHANICAL DRAFTING AND CREATIVE SKETCHING.* Credit 3 hrs. Spring. 1 Lect. 2 Lab. Prereq., 3111. Basic mechanical drafting principles and standards; creation, expression, and interpretation of specifications for the properties of mechanical anatomy by layouts and working drawings; continuation of creative sketching.

Upson Hall, largest of the new engineering buildings, completed in 1958, houses the Sibley School of Mechanical Engineering.


UPSON HALL

3114. *FREEHAND DRAWING.* Credit 1 hr. Fall. 1 Lect. For students who desire only the freehand content of 3111.

3115. *CREATIVE SKETCHING.* Credit 1 hr. Spring. 1 Lect. Prereq., 3111 or 3114. For students who desire only the creative sketching content of 3112.

3116. *INTRODUCTION TO INDUSTRIAL DESIGN.* Credit 3 hrs. Spring. 2 Lab. Prereq., 3111 and 3112. Readings; abstract and applied design problems which investigate and apply the interrelationships existing between form, function, and materials.

3117. *DESCRIPTIVE GEOMETRY.* Credit 2 hrs. Fall. 2 Lab. Same as 3111 except that freehand content is omitted.

3118. *BASIC MECHANICAL DRAFTING.* Credit 2 hrs. Spring. 2 Lab. Same as 3112 except that creative sketching content is omitted.

3119. *INTRODUCTIORY MECHANICAL DRAFTING AND SKETCHING.* For chemical and metallurgical engineering students. Credit 2 hrs. Fall. 2 Lab. Basic mechanical drafting and sketching; lettering; delineation; projective and pictorial drawing; selected topics of descriptive geometry; flow charts and graphs; basic drafting techniques.

3120. *MECHANICAL DRAFTING AND SKETCHING.* For chemical and metallurgical engineering students. Credit 1 hr. Spring. 1 Lab. Prereq., 3119 or permission. Continuation of basic principles and standards of drafting; making and interpreting machine layouts and working drawings; piping diagrams.

3131. *SPECIAL PROBLEMS IN DRAFTING OR INDUSTRIAL DESIGN.* Credit based upon actual hours of work. Fall or spring. Lab. as required. Also may be elected by students who desire the first term only of the Industrial Design Project.

3198, 3199. *INDUSTRIAL DESIGN PROJECT.* Total credit 6 hrs. Ninth and tenth terms. 2 Lab. Prereq., 3116. Project work includes readings and design problems. Readings integrate design with the contemporary social and economic scene. Design problems are directed toward creation of a comprehensive attitude in product development and toward attainment of a measure of design ability.

INDUSTRIAL AND ENGINEERING ADMINISTRATION

Messrs. Allderige, Allen, Bechhofer, Conway, Gavett, Goode, Hanselman, Kao, Krick, Loberg, Sampson, Saunders, Schultz, and Weiss.

3231. *PRINCIPLES OF INDUSTRIAL ACCOUNTING AND COST FINDING.* Credit 3 hrs. Fall and spring. 2 Lect. 1 Comp. Basic course in principles of industrial accounting including controlling accounts; special journals and ledgers; voucher system; manufacturing cost systems.

3232. *PERSONNEL MANAGEMENT.* Credit 3 hrs. Fall. 3 Rec. Intended for graduate students but open to qualified undergraduates. Prereq., 3241 or permission. Techniques of employee selection and evaluation, job evaluation, training, motivation; personnel department organization and interdepartmental relations.

3233. *REPORT WRITING.* Credit 1 hr. Offered on demand. 1 Rec. Engineering students only. Organization of engineering material into concise written form; preparation of engineering reports including organization, description of apparatus and procedures, graphical presentation and summary of results; business letters; written specifications.

3235. *INDUSTRIAL ORGANIZATION AND MANAGEMENT.* Credit 3 hrs. Fall. 3 Lect. Management of an industrial enterprise; internal organization; effect of

type of product, methods of manufacture, size of enterprise, and personnel involved; types of enterprises; plant location; centralization and decentralization trends; diversification and specialization; growth of industry.

3236. *ORGANIZATION AND MANAGEMENT OF PRODUCTION.* Credit 3 hrs. Spring. 2 Lect. 1 Rec. Introductory course in industrial management covering organizational structure; principles of mass production; plant location and layout; methods analysis and time study; production planning and control; related functions of engineering, research, sales, purchasing, and cost control; technology, technical organization, and background of scientific management.

3240. *ANALYTICAL METHODS IN OPERATIONS RESEARCH.* Credit 3 hrs. 3 Rec. Intended for graduate students but open to qualified undergraduates. Prereq., calculus. Selected topics of special interest in operations research and industrial engineering including matrix algebra, set theory, convex bodies, linear inequalities, probability theory (including Markoff chains), and applications to selected problems.

3241. *INDUSTRIAL AND ENGINEERING STATISTICS.* Credit 3 hrs. Fall and spring. 2 Rec. 1 Comp. Prereq., calculus. Applications of probability theory and statistics to industrial and engineering problems; point and confidence interval estimation; statistical testing of hypotheses; properties of binomial, Poisson, and hypergeometric distributions, and applications to sampling inspection problems; large-sample theory and the normal distribution, small-sample theory and student's T and Chi-square distributions; introduction to correlation theory and curve fitting by least squares.

3242. *STATISTICAL CONTROL AND SAMPLING INSPECTION.* Credit 3 hrs. Spring. 2 Rec. 1 Comp. Elective for qualified undergraduate and graduate students. Prereq., 3241 or permission. Underlying theory, assumptions, applications, and limitations of control charts and sampling plans; concept of statistical control, Shewhart control charts, and sampling inspection for attributes and variables; organization, administration, and economic problems, and application of concepts to areas other than quality maintenance.

3243. *INTERMEDIATE INDUSTRIAL AND ENGINEERING STATISTICS.* Credit 3 hrs. Spring. 2 Rec. 1 Comp. Intended for graduate students but open to qualified undergraduates. Prereq., 3241 or permission. Application of statistical methods to the efficient design, analysis, and interpretation of industrial and engineering experiments; rational choice of sample size for various statistical tests and the operating characteristic curves of these tests; curve fitting by least squares; introduction to the analysis of variance.

3244. *ADVANCED INDUSTRIAL AND ENGINEERING STATISTICS.* Credit 3 hrs. Fall. 2 Rec. 1 Comp. Intended for graduate students. Prereq., 3243 or permission. Use and analysis of experimental designs such as randomized blocks and Latin squares; analysis of variance and covariance; factorial experiments; statistical problems associated with finding best operating conditions; statistical multiple-decision selection procedures.

3245. *SELECTED STATISTICAL TOPICS.* Credit 3 hrs. Spring of odd years. 2 Rec. 1 Comp. Intended for graduate students. Prereq., 3243 or permission. Selected topics chosen from such fields as nonparametric statistical methods, sequential analysis, multivariate analysis.

3246. *PRINCIPLES OF INDUSTRIAL ACCOUNTING.* Credit 2 hrs. Fall. 1 Lect. 1 Comp. Basic accounting theory; special journals; controlling accounts and subsidiary records; voucher system; basic manufacturing cost accounting.

3247. *PRINCIPLES OF COST CONTROL.* Credit 3 hrs. Spring. 2 Lect. 1 Comp. Prereq., 3246 or 3231, or equivalent. Principles of cost accounting for production

order and continuous process operations; cost factors related to decision making, control and profit; budgets and standards; cost analyses.

3253. *INDUSTRIAL ACCOUNTING AND COST CONTROL.* Credit 3 hrs. Fall. 2 Lect. 1 Comp. An accelerated course for upperclassmen and graduate students. Basic accounting theory; manufacturing cost accounting and cost analysis; cost factors related to decision making, control and profit; budgets and standards.

3254. *ANALYTICS OF DECISION AND CONTROL.* Credit 3 hrs. Fall. 2 Rec. 1 Comp. Elective for graduate students and qualified undergraduates. Prereq., 3241, 3247, or 3263. The theory of economic decision making. Decision criteria, treatment of uncertainty, cost concepts for decision making, cost equivalence in time, quantitative methods of decision making for problems of allocation, assignment, distribution, conflict, and control.

3261. *MANUFACTURING ENGINEERING.* Credit 3 hrs. Spring. 2 Rec. 1 Lab. Elective for graduate students. Prereq., 3247 or 3253, 3262, 3404 or equivalent. Economics applied to capital investment decisions; analytical techniques for process design, plant layout, materials handling, production management.

3262. *METHODS ENGINEERING.* Credit 3 hrs. Fall and spring. 1 Lect. 2 Lab. Prereq., 3241 or equivalent. Analysis and design of operations and jobs; factors influencing creation and evaluation of alternative designs; work measurement and other techniques including stop-watch time study, work sampling, queueing, and predetermined motion times as used for evaluation of design, control of operations, wage standards, etc.

3263. *PRODUCTION ENGINEERING.* Credit 3 hrs. Fall. 2 Rec. 1 Comp. Prereq., 3247 or 3253 and 3262. Basic concepts involved in the design and operation of production systems. Various cost concepts, certain types of cost analysis, and the economics of capital investment decisions. The fundamentals of production and inventory control. Simple linear programing and assignment problems involved in plant design.

3264. *PRODUCTION ENGINEERING.* Credit 3 hrs. Spring. 2 Rec. 1 Comp. Prereq., 3263. The analysis and design of production systems. Emphasis will be placed on analytical methods and procedures. The material will include such topics as the statistical analysis of product designs and specifications, process capability studies, process planning including process automation, plant layout and design, and materials handling.

3265. *PRODUCTION PLANNING.* Credit 3 hrs. Spring. 2 Rec. 1 Comp. Intended for graduate students but open to qualified undergraduates. Prereq., 3241, 3261 or 3263, or permission. Scheduling of manufacturing operations—forecasting, leveling, explosion, loading, sequencing. The planning and control of inventories. Emphasis on mathematical and statistical methods of performing these functions, including development of decision rules and reactive control systems.

3266. *ADVANCED METHODS ENGINEERING.* Credit 3 hrs. Fall. 2 Rec. 1 Lab. Intended for graduate students but open to qualified undergraduates. Prereq., 3262 or permission. Analysis of methods engineering techniques and means of appraising specific installations; advanced treatment of work sampling, macroscopic and microscopic standard data, maintenance of time standards, and other techniques.

3267. *ADVANCED PRODUCTION ENGINEERING.* Credit 3 hrs. Fall. 2 Rec. 1 Lab. Intended for graduate students but open to qualified undergraduates. Prereq., 3264 or 3261. A continuation of 3264 but with emphasis on the isolation and analysis of production problems concerned with material flow, material handling methods, and plant design.

3270. *INDUSTRIAL MARKETING.* Credit 3 hrs. Spring. 3 Lect. Elective for qualified undergraduate and graduate students. Prereq., 3241, 3247 or 3253. Industrial marketing as related to product planning, policy, and research, sales and market analysis; distribution channels; pricing and terms of sale; sales promotion; management and organization of sales force; sales control. Aspects of related purchasing problems; methods of forecasting sales.

3271. *INDUSTRIAL MARKETING RESEARCH.* Credit 3 hrs. Fall. Intended for graduate students but open to qualified undergraduates. Prereq., 3270. Techniques of market research applied to specific problems related to industrial goods.

3280. *INTRODUCTION TO OPERATIONS RESEARCH.* Credit 3 hrs. Fall. 2 Rec. 1 Comp. Intended for graduate students and qualified fifth year students. Prereq., 3241 or permission. Methodology and techniques of operations research including waiting line models, linear programing and assignment, simulation, and other specialized techniques; applications to production, cost, inventory, and sales problems.

3281. *COMPUTING EQUIPMENT AND INDUSTRIAL APPLICATIONS.* Credit 3 hrs. 2 Rec. 1 Comp. Intended for graduate students but open to qualified undergraduates. Prereq., 3247, 3262 or permission. Principles and characteristics of modern high-speed digital and analog computing equipment. Programing and operation of the digital computer at the Cornell Computing Center. Engineering and scientific computing applications, introduction to numerical analysis, simulation and Monte Carlo techniques. Data processing applications in accounting, communications and control; problems of integrated systems design.

3284. *MATHEMATICAL PROGRAMING AND DECISION THEORY.* Credit 3 hrs. 2 Rec. 1 Comp. Spring of even years. Intended for graduate students. Prereq., 3240 and 3243, or equivalent. Linear and dynamic programing applied to problems of allocation, assignment, and distribution. Statistical decision theory, relation to game theory, structure of games, strategies; the emphasis of this course will be on the basic concepts and applications.

3290. *SPECIAL INVESTIGATIONS IN INDUSTRIAL AND ENGINEERING ADMINISTRATION.* Credit and sessions as arranged. Fall and spring. Elective for qualified undergraduate and graduate students. Offered to qualified students individually or in small groups. Study, under direction, of special problems in the field of industrial and engineering administration.

3291. *INDUSTRIAL AND ENGINEERING ADMINISTRATION GRADUATE SEMINAR.* Credit 1 hr. A weekly 1½ hr. meeting. Intended for graduate students. Discussion and study of assigned topics of importance in the field.

3298, 3299. *PROJECT.* Max. credit 6 hrs. Prereq., 3264. Project work requires the identification and analysis of both professional and research problems in industrial engineering. The projects emphasize analytic ability and the synthesis of feasible solutions. Projects can be done individually or in groups up to eight. The problem definition and the subsequent analysis and synthesis are the concern of the student with minimal faculty guidance and participation.

MACHINE DESIGN

Messrs. Burr, DuBois, Mabie, Ocvirk, Phelan, and Wehe.

3341. *MACHINE DESIGN.* Credit 4 hrs. Fall and spring. 3 Rec. 1 Comp. Prereq., 1153, 1241, 3118, 3402, and 6110, or equivalent. Required of students in electrical engineering and agricultural engineering and may be elected by other qualified students not in mechanical engineering. The design of machines and machine members

based upon considerations of motion, size, material, strength, durability, and manufacturing processes; selection of cams, linkages, couplings, clutches, brakes, bolts, chains, gears, bearings, shafts, springs, and fasteners.

3351. *MECHANISM.* Credit 3 hrs. Fall. 2 Rec. 1 Lab. Prereq., 3112, 1151. An analysis of displacements, linkages, cams, gears, trains of mechanism, and computing linkages; and introduction to synthesis of mechanisms.

3352. *DYNAMICS OF MACHINERY.* Credit 3 hrs. Spring. 2 Rec. 1 Lab. Prereq., 3351 and 1152. Graphical and analytical studies of velocities and accelerations and of static and inertia forces in mechanism; engine force analysis, flywheels, and balancing; gyroscopic loads; shaft whirl; vibration isolation.

3353. *DESIGN OF MACHINE MEMBERS.* Credit 3 hrs. Fall. 2 Rec. 1 Comp. Prereq., 3351, 1153, 1241 (prereq. or parallel). Application of mechanics, kinematics, materials, and processes to the design and selection of springs, couplings, clutches, brakes, belts, chains, gears, shafts, bearings, fastenings, and pressure vessels; stress concentration, residual stresses, theory of lubrication.

3354. *DESIGN OF MACHINES.* Credit 3 hrs. Spring. 1 Lect. 2 Lab. Prereq., 3353, 3404, 1242 (prereq. or parallel). The design of complete machines and modification of existing machines; computations and layout drawings as required; the design of castings, forgings, stampings, weldments, housings, and hydraulic systems for machines.

3361. *ADVANCED MACHINE ANALYSIS.* Credit 3 hrs. Fall. 3 Rec. Intended for graduate students but open to qualified fifth year students. Prereq., 3353, 1155 (prereq. or parallel). Advanced analyses of mechanisms and machinery members such as clutches and brakes; the graphical determination of shaft deflection; problems in impact, creep, thermal stress, residual stress, surface stress, pressure vessels, and rotating disks; and extended treatment of bearing lubrication.

3362. *MECHANICAL DESIGN OF TURBOMACHINERY.* Credit 3 hrs. Spring of odd years. 3 Rec. Intended for graduate students but open to qualified fifth year students. Prereq., 1154 or 3361, 3352 or 3367 (prereq. or parallel). Mechanical design of major components of high speed compressors and turbines for structural adequacy and vibration-free operation. Selected topics from among the following: design of rotor components: disks, vanes, blades, shafts, and connections. Design of casing components: cylindrical, conical, torical shells; flat plates and diaphragms. Design of bearings, seals, gaskets, expansion members. Investigation of natural frequencies and critical speeds. Selection of materials.

3366. *ADVANCED KINEMATICS.* Credit 3 hrs. Spring of even years. 2 Rec. 1 Lab. Prereq., 3352. Advanced analytical and graphical treatment of velocities and accelerations. Further treatment of Coriolis' acceleration. Advanced analysis and design of cams, gears, and computing mechanisms. Synthesis of mechanism.

3367. *DESIGN PROBLEMS IN VIBRATIONS AND DYNAMICS.* Credit 3 hrs. Spring. 2 Lect. 1 Lab. Prereq., 1155, 3352. Applications of dynamics and vibration theory to the design of machinery; vibration and shock mounting of machines with single and multi degrees of freedom, properties of isolators, damping devices, critical speeds of shafts and crankshaft systems; vibration instruments and experimental investigations.

3370. *SPECIAL INVESTIGATIONS IN MACHINE DESIGN.* Credit arranged. Either term. Individual work or work in small groups under guidance in the design and development of a complete machine, in the analysis of experimental investigation of a machine or component of a machine, or studies in a special field of machine design.

3372. *EXPERIMENTAL METHODS IN MACHINE DESIGN.* Credit 3 hrs. Fall. 1 Rec. 2 Lab. Prereq., 3353 or 3341. Investigation and evaluation of methods used to obtain design and performance data. Techniques of photoelasticity, strain measurement, photography, vibration and sound measurements, balancing methods, and development techniques are studied as applied to machine design problems.

3374. *CREATIVE DESIGN.* Credit 3 hrs. Fall. 2 Lab. Prereq., 3354. Short problems to stimulate ingenuity and originality, emphasizing methods for the development of improved designs.

3375. *AUTOMATIC MACHINERY.* Credit 3 hrs. Fall. 2 Rec. 1 Lab. Field trips. Prereq., 3351. A study of automatic and semiautomatic machinery such as dairy, canning, wire-forming, textile, machine-tool, computing, and printing equipment.

3376. *FLUID POWER AND CONTROL.* Credit 3 hrs. Spring. 2 Rec. 1 Lab. Prereq., 3353 and 3603 or equivalent. Methods of generation, application, and control of oil hydraulic and pneumatic power; modes of automatic control; components of industrial controllers; automatic control systems.

3377. *AUTOMOTIVE ENGINEERING.* Credit 3 hrs. Fall of odd years. 3 Rec. Prereq., 3353. Analysis of various designs for the parts of an automotive vehicle, other than the engine, in relation to its performance; stability, weight distribution, traction, steering, driving, braking, riding comfort, power required and available, transmission types, acceleration, and climbing ability. Recommended together with Course 3670 for a study of automotive engineering.

3391. *MACHINE DESIGN SEMINAR.* 1 hr. credit at the end of 2 terms. A one-and-a-half-hour meeting approximately every other week. Required of graduate students majoring in machine design. Discussion and study of assigned topics of importance in the field, by faculty, graduate students, and outside speakers.

3398, 3399. *PROJECT.* Total credit 6 hrs. Work of the ninth and tenth terms in the form of projects to integrate the training in mechanical engineering when such work is done principally in the field of machine design.

MATERIALS PROCESSING

Messrs. Carpenter, Dispenza, Geer, Moltrecht, and Morgan

3402. *MACHINE TOOLS.* Credit 2 hrs. Either term. 1 Lect. 1 Lab. Lectures, demonstrations, and laboratory practice on basic machine tools and their accessories; project layout and operation sequence exercises for unit making of goods; demonstrations of production tooling and gaging.

3403. *FUNDAMENTALS OF MACHINE TOOLS.* Credit 1 hr. Either term. 1 Lect. 1 Lab. Demonstrations and practice on basic machine tools and their accessories; use of unit measuring instruments.

3404. *PRODUCTION MACHINE TOOLS.* Credit 2 hrs. Either term. 1 Lect. 1 Lab. Prereq., 3406, 3262. Lectures, demonstration studies, and analyses of machine tools for quantity production of goods; jigs, fixtures, and other tooling accessories are investigated; operation analysis and quality limitations are discussed and demonstrated.

3405. *GAGE LABORATORY.* Credit 1 hr. Either term. 1 Lab. Demonstration studies of measuring devices and techniques for control of size, form, and alignment of commercial goods to A.S.A. and other standards; laboratory practice in inspection methods; quality control data studies; calibration and gage checking.

3406. *MACHINE TOOL TECHNOLOGY.* Credit 2 hrs. Either term. 1 Lect. 1 Lab. Study of chip formation, cutting tools and fluids, speeds and feeds, and their relations

to machinability; analyses of general purpose machines and their accessories; machining practice including layouts, set-ups, and use of measuring instruments.

3407. *ADVANCED MATERIALS PROCESSING.* Credit and hours as arranged with department. Special work in selected areas of mechanical technology; topics and extent of study assigned to suit individual or group needs.

3411. *CUTTING TOOLS.* Credit 3 hrs. Either term. 2 Lect. 1 Lab. Prereq., 3404, 1152, 1231. Physics of chip formation; tool life, Woxen's and Ernst-Merchant equations; machinability factors; tool preparation; cutting fluid performance; work-tool relations.

3412. *MACHINE TOOL OPERATIONS.* Credit 3 hrs. Either term. 2 Lect. 1 Lab. Prereq., 3404, 3262, 3405. An advanced and detailed study of production machinery and tooling; operation sequence; fixture and cutter selection; transfer schemes; special machinery; quality limitations.

3413. *MACHINE TOOL ANALYSIS.* Credit 3 hrs. Either term. 1 Lect. 2 Labs. Prereq., 3404, 3262, 3351. An intensive investigation of machine tool capacities, standard tooling and dimensions of elements; analysis of power drives, speeds and feeds; performance studies; vibration and rigidity problems; maintenance and lubrication; machine tool manufacture; industrial needs and development trends.

3425. *ADVANCED GAGE LABORATORY.* Credit 3 hrs. Either term. 1 Lect. 2 Labs. Prereq., 3405, 1222, 3241. Intensive study of gaging principles and practices; quality control applications; continuous gaging and automatic sorting; selective assembly; noncontact and nondimensional inspection; machine tool inspection standards.

3498, 3499. *PROJECT.* Total credit 6 hrs. Work of the 9th and 10th terms in the form of projects to integrate the training in mechanical engineering when such work is done principally in the field of materials processing.

THERMAL ENGINEERING

Messrs. Andrae, Conta, Dropkin, Erdman, Fairchild, Gebhart, Mackey, McManus, Powell, Shepherd, and Watson.

3601. *ENGINEERING THERMODYNAMICS.* Credit 3 hrs. Fall. 1 Lect. 2 Rec. Prereq., Mathematics 163, Physics 122, Chemistry 106. Laws of thermodynamics; energy equations; thermodynamic properties of state of ideal and real fluids; thermodynamic analysis of processes of ideal and real fluids.

3602. *ENGINEERING THERMODYNAMICS.* Credit 3 hrs. Spring. 1 Lect. 2 Rec. Prereq., 3601, Chemistry 402. Combustion; thermodynamics of ideal gas reactions; thermodynamic analysis of basic cycles used for power, refrigeration, and air conditioning.

3603. *FLUIDS ENGINEERING I.* Credit 3 hrs. Spring. 3 Rec. Prereq., 3601, 1152. Properties of fluids, hydrostatic relations; kinematics and dynamics of fluids; incompressible and compressible flow in ducts; stagnation properties; laminar flow, turbulent flow, boundary layer, velocity distribution; compressible flow with varying area, friction, and heat transfer; normal shock.

3604. *FLUIDS ENGINEERING II.* Credit 3 hrs. Fall. 2 Rec. 1 Lab. Prereq., 3603. Dimensional analysis; flow metering; flow over immersed bodies; boundary layer; drag in incompressible and compressible flow; oblique shocks; vortex flow; energy transfer between a fluid and a rotor; characteristics of turbomachines; reaction and efficiency; pressure distribution and lift; propulsion systems; hydrodynamic couplings.

3605. *HEAT TRANSFER.* Credit 3 hrs. Fall. 2 Rec. 1 Lab. Prereq., 3603, 1155. Introduction to heat transfer by conduction, convection, and radiation; steady state, transient state; steady periodic state; heat transfer in engineering apparatus; numerical methods; electrical and fluid analogues. Laboratory instruction in temperature measurement, determination of surface coefficients, radiant energy exchange, and experimental use of analogues.

3606. *THERMAL ENGINEERING LABORATORY.* Credit 3 hrs. Spring. 1 Lect. 1 Lab. Prereq., 3602, 3604, 3605. Methods of testing; experimental determination of performance characteristics of engines, turbines, steam generating units, pumps, compressors, fans, refrigerating systems, air conditioning apparatus, auxiliaries and components of complete plants; analysis of experimental data; preparation of engineering reports.

3607. *COMBUSTION ENGINES.* Credit 3 hrs. Fall and spring. 3 Rec. Prereq., accompanied or preceded by 3606. Introduction to combustion engines with emphasis on application of thermodynamics, fluid dynamics, and heat transfer; recriprocating combustion engines; gas turbines; compound engines; reaction engines.

3608. *THERMAL POWER PLANTS.* Credit 3 hrs. Fall and spring. 3 Rec. Prereq., accompanied or preceded by 3606. Introduction to steam and binary vapor power plants with emphasis on applications of thermodynamics, fluid dynamics, and heat transfer; nuclear power.

3609. *REFRIGERATION AND AIR CONDITIONING.* Credit 3 hrs. Fall and spring. 3 Rec. Prereq., accompanied or preceded by 3606. Introduction to refrigeration and air conditioning with emphasis on applications of thermodynamics, fluid dynamics, and heat transfer; compression, absorption, and other systems of refrigeration; control of the physical environment.

3630. *ENGINEERING THERMODYNAMICS.* Credit 3 hrs. 3 Rec. Required of students in the Schools of Electrical Engineering and Civil Engineering. Prereq., Mathematics 163, Physics 122, Chemistry 106. Laws of thermodynamics; energy equations; thermodynamic properties of state of gases and vapors, nonflow and flow processes; gas and vapor cycles; refrigeration; steam turbines.

3642. *HEAT-POWER.* Credit 2 hrs. Spring. 2 Lect. Required of students in the School of Civil Engineering. Prereq., 3630. Vapor cycles; heat transfer; the elementary steam power plant; compressors; internal combustion engines; air conditioning.

3650. *SPECIAL TOPICS IN THERMAL ENGINEERING.* Spring. Credit to depend upon hours of actual work. Informal instruction will be given to a limited number of students interested in work to supplement that given in courses in combustion engines, power generation, fluid dynamics, heat transfer, refrigeration, air conditioning, and instruments; permission of the department necessary for registration.

3651. *GRAPHICAL SOLUTIONS.* Credit 3 hrs. Spring. 3 Rec. Elective for undergraduate students who have completed four terms or for graduate students. Design of slide rules, network charts, and alignment charts; derivation of empirical equations to fit experimental data; errors and precision of measurement.

3652. *THEORY OF GAS PROCESSES AND COMBUSTION.* Credit 3 hrs. Spring. 3 Lect. Intended for graduate students and qualified fifth year students who want a basic preparation in the molecular theory of gases for application to combustion and related phenomena. Fundamental concepts from statistical mechanics and kinetic theory; heat, mass, and momentum transport and chemical reaction processes are investigated; applications are made to topics in combustion and related subjects.

3661. *ADVANCED THERMODYNAMICS.* Credit 3 hrs. Fall. 3 Rec. Intended for graduate students but open to qualified fifth year students. Prereq., 3601, 3602, or

equivalent. A rigorous and general treatment of the laws of thermodynamics with emphasis on mathematical development and philosophical interpretations; the pure substance; homogeneous and heterogeneous systems; Gibbs and Helmholtz functions; Maxwell relations; availability and irreversibility; equilibrium.

3662. *GAS TURBINE PLANTS.* Credit 3 hrs. Spring. 3 Lect. Prereq., 3601, 3602, or equivalent (3663 desirable). Study of the cycles and apparatus of the modern gas turbine plant; performance and suitability for various applications.

3663. *ADVANCED TURBOMACHINERY.* Credit 3 hrs. Fall. 3 Rec. Intended for graduate students but open to qualified fifth year students. Prereq., 3602, 3603, 3604, or equivalent. Transfer of energy between a fluid and a rotor; application of thermodynamics and fluid dynamics to rotating machinery; centrifugal and axial flow pumps, compressors, and turbines.

3664. *ADVANCED FLUID MECHANICS.* Credit 3 hrs. Spring. 3 Rec. Intended for graduate students but open to qualified undergraduates. Prereq., 3602, 3604. More advanced treatment of some of the topics in 3603 and 3604, with particular reference to two-dimensional ideal flow; laminar and turbulent boundary layer; turbulence and turbulent flow in ducts; compressible flow; method of characteristics.

3665. *ADVANCED HEAT TRANSFER.* Credit 3 hrs. Fall. 3 Rec. Prereq., 3605 or consent of instructor. Basic modes of heat transfer are emphasized. Analytic methods are employed, and results are compared with experimental correlations. Solutions of selected heat conduction problems, a general method of analysis for diffuse radiation, differential similarity, boundary layer convection solutions, heat and momentum similarity theory, phase change processes, and an introduction to numerical methods.

3666. *ADVANCED AIR CONDITIONING.* Credit 3 hrs. Fall. 3 Rec. Selected studies of air conditioning principles and air conditioning apparatus; solar loads and solar collectors; heat pumps; air conditioning in transportation; thermoelectric refrigeration.

3667. *TEMPERATURE MEASURING INSTRUMENTS.* Credit 3 hrs. Spring. 2 Lect. 1 Lab. Intended for graduate students but open to qualified undergraduates. Prereq., 3605. Theory, construction, calibration, and application of liquid-in-glass thermometers, solid expansion thermometers, pressure-spring thermometers, resistance thermometers, thermoelectric thermometers, optical pyrometers, radiation pyrometers.

3670. *ADVANCED COMBUSTION ENGINES.* Credit 3 hrs. Spring. 3 Rec. Intended for graduate students but open to qualified undergraduates. Prereq., 3604, 3607, (or equivalent). Advanced study of topics in field of reciprocating engines, both spark-ignition and diesel. Methods of thermodynamic analysis and performance prediction for free-piston power plants and supercharged engines. Relation of engine performance characteristics and performance characteristics of automotive vehicles. Recommended together with Course 3377 for study in automotive engineering.

3671. *AIRCRAFT AND MISSILE PROPULSION SYSTEMS.* Credit 3 hrs. Fall. 3 Rec. Prereq., 3603, 3604, 3607 or equivalent. Intended for graduate students but open to qualified fifth year students. Application of thermodynamics and fluid mechanics to the analysis and design of thermal-jet and rocket engines. Consideration of advanced methods of propulsion.

3680. *ADVANCED CONVECTION HEAT TRANSFER.* Credit 3 hrs. Fall. 3 Rec. Prereq., 3605 or consent of instructor. Processes of transfer of heat, momentum, and mass in fluids are considered in detail. Theories of transfer processes and analytic solutions are presented. Analytical and experimental results are compared. Transfer differential equations for a fluid, delineation of kinds of processes and differential

similarity, natural convection, forced convection at low and high velocities, some techniques of boundary layer solution, similarity theories, effects of turbulence, and experimental results for cases not readily solved by analytic methods.

3681. *ADVANCED CONDUCTION AND RADIATION HEAT TRANSFER.* Credit 3 hrs. Spring. 3 Rec. Prereq., 3605 or consent of instructor. Theories of conduction mechanisms are reviewed. The conduction of heat in solids is considered for various cases of steady, unsteady, and periodic heat flow with and without internal sources. Mathematical, numerical, and analogue methods of problem solution are presented. The various types of thermal radiation processes in solids and gases are discussed. Spatial and specular distributions are considered. Methods of calculation are presented for radiation in the absence and in the presence of absorbing and emitting gases.

3691. *THERMAL ENGINEERING SEMINAR.* Credit 1 hr. at the end of 2 terms. A one-and-a-half-hour meeting approximately every other week. Required of all graduate students with major subject in the Department of Thermal Engineering. Talks by graduate students, staff members, and invited guests.

3698, 3699. *PROJECT.* Total credit 6 hrs. Work of the ninth and tenth terms to integrate the training in mechanical engineering, principally in the fields of thermodynamics, fluid dynamics, heat transfer, combustion engines, power plants, refrigeration, and air conditioning.

ELECTRICAL ENGINEERING

The descriptions of courses offered in the School of Electrical Engineering follow. Courses in other divisions required of students in electrical engineering are described on pages 135–145.

REQUIRED COURSES

4021. *TECHNICAL WRITING AND PRESENTATION.* Credit 3 hrs. Fall. 3 Lect.-Rec. The development of the basic principles of exposition, the knowledge of suitable form, and the appreciation of function that will enable students to write and present reports and communications that meet professional standards.

4041. *NONRESIDENT LECTURES.* Credit 1 hr. Fall. 1 Lect. Given by lecturers invited from industry and from certain other departments of the University to assist students in their approach to employment and in their transition from college to industrial life.

4101. *ELECTRICAL SCIENCE I.* Credit 3 hrs. Fall. 2 Lect. 2 Rec. Prereq., Math. 162, Phys. 122. Electric field, potential, and flux density; capacitance; networks of capacitors; introduction to matrices and determinants; energy in electric field; forces on charged conductors; conductance and resistance; networks of resistors; vacuum tubes.

4102. *ELECTRICAL SCIENCE II.* Credit 3 hrs. Spring. 2 Lect. 2 Rec. Prereq., Math. 163, 4101. Magnetic flux density and field strength; inductance; forces of magnetic origin; magnetic circuits; transformers; energy flow in electromagnetic field; displacement currents; induced voltage and simple generator; networks of inductors; force and energy in magnetic fields.

4103. *MATHEMATICAL ANALYSIS OF LINEAR SYSTEMS.* Credit 3 hrs. Spring. 2 Lect. 1 Comp. Prereq., Math. 163. Differential equations of simple electric circuits; algebra of complex numbers; algebraic and exponential functions of a complex variable; the complex exponential time-function; impedance, admittance and power;

differentiation and integration in the complex plane for algebraic functions, exponential functions, and products thereof; Fourier synthesis and analysis.

4112. *ALTERNATING CURRENT CIRCUITS.* Credit 3 hrs. Fall. 1 Lect. 1 Rec. 1 Comp. Prereq., 4102, 4103. Elementary a-c circuit analysis; application of vector algebra and vector diagrams; power and energy relationships; equivalent circuits of air and iron-core transformers; polyphase circuits and power measurement; four-terminal networks; image parameters and relation to A, B, C, D constants; analysis in the complex frequency plane.

4113. *TRANSMISSION LINES AND FILTER NETWORKS.* Credit 3 hrs. Spring. 1 Lect. 1 Rec. 1 Comp. Prereq., 4112. Steady state solution, characteristic impedance and propagation constant; reflection coefficient; vector diagrams; impedance charts as graphical aids; transmission line networks; impedance transformations; network image and iterative operation, transfer constants; constant K, m derived, and lattice types; Foster's theorem; Bartlett's theorem; composite filter design; wave guides; transmission line analogue in solution of guide problems; modes; impedance transformations.

4114. *TRANSIENTS IN LINEAR SYSTEMS.* Credit 3 hrs. Fall. 1 Lect. 1 Rec. 1 Comp. Prereq., 4112. Transient behavior of circuits with lumped constants; the classical solution of single- and double-energy circuits in the transient state; the ordinary linear differential equation; the Laplace transformation; systems of ordinary linear differential equations, their Laplace transformation, and their solution.

4116. *ELECTRIC CIRCUIT LABORATORY.* Credit 3 hrs. Fall. 1 Lect. 1 Lab. Prereq., 4102 or 4983. D-c circuits and parameters; d-c bridges; temperature measurements; heat flow; instruments; calibration and standards; transients.

4121. *INTRODUCTION TO ELECTRONICS AND NONLINEAR ANALYSIS.* Credit 4 hrs. Spring. 2 Lect. 1 Rec. 1 Lab. Prereq., 4116 and 4112 or 4983. Study of electrical conduction in vacuum, ionized gases, and semiconductors, and of the characteristics of devices employing these phenomena; the large-signal behavior of these devices in such circuits as rectifiers, clipping and champing circuits, amplitude modulators and demodulators, and class A, B, and C amplifiers.

4122. *LINEAR ANALYSIS OF ELECTRONIC CIRCUITS.* Credit 4 hrs. Fall. 2 Lect. 1 Rec. 1 Lab. Prereq., 4121. Small-signal equivalent circuits are developed for general n-terminal devices and applied to triodes, multi-element tubes and transistors; small-signal analysis of such circuits as voltage regulators, vacuum-tube and transistor bridges, and R-C coupled, transformer-coupled, tuned, multistage and feedback amplifiers.

4123. *ELECTRONIC CIRCUIT ELEMENTS.* Credit 4 hrs. Spring. 3 Lect.-Rec. 1 Lab. Prereq., 4122. Primarily a study of circuits that utilize nonlinear properties of electron devices. Vacuum tube and transistor circuits considered include oscillators and multivibrators; wave-shaping, gating, trigger, and delay circuits; amplitude, angular, and pulse modulation and demodulation. Additional topics include elements of electronic computers, noise in vacuum tube and transistor circuits, magnetic and parametric amplifiers.

4216. *ELECTRICAL MACHINERY LABORATORY.* Credit 4 hrs. Spring. 1 Lect. 1 Rec. 1 Lab. Prereq., 4116. D-c magnetization; d-c motors; d-c controllers; d-c generators; amplidyne; loss separation; a-c magnetization; a-c bridges.

4221. *ALTERNATING CURRENT MACHINERY.* Credit 4 hrs. Fall. 1 Conf. 1 Comp. Prereq., 4112, 4216. Theory, construction, and operating characteristics of transformers, induction motors, synchronous machines, and single-phase motors.

4226. *ELECTRICAL MACHINERY LABORATORY.* Credit 4 hrs. Spring. 1 Lect. 1 Rec. 1 Lab. Prereq., 4221. Magnetization and circuits with nonsinusoidal voltages.

Phillips Hall, erected in 1955, houses the School of Electrical Engineering.

Harmonics in polyphase systems; instrument, constant current, and constant potential transformers; single-phase and polyphase induction motors; synchronous machines.

ELECTIVE AND GRADUATE COURSES

GENERAL

4090. *SPECIAL TOPICS IN ELECTRICAL ENGINEERING.* Credit 1 to 3 hrs. Seminar, reading course, or other special arrangement agreed upon between the students and faculty members concerned.

4091 and 4092. *PROJECT.* Credit 3 hrs. Fall and spring. Individual study, analysis, and usually experimental tests in connection with a special engineering problem chosen by the student after consultation with the faculty member directing his project; an engineering report on the project is required.

POWER SYSTEMS AND MACHINERY

4321. *ELECTRICAL MACHINE THEORY.* Credit 3 hrs. Fall. 1 Conf. 1 Comp. Prereq., 4226. Space harmonics; parasitic torques; two-reaction analysis; transient impedances; symmetrical component impedances; single-phase motor analysis; commutator-type a-c machines.

4326. *ELECTRICAL MACHINERY LABORATORY.* Credit 3 hrs. Spring. 1 Lect. 1 Lab. Prereq., 4321. Salient-pole synchronous machines; induction motor loss separation; energy metering; special topics.

4351. *POWER SYSTEMS I.* Credit 3 hrs. Fall. 2 Lect.-Rec. 1 Lab.-Comp. Prereq., 4113, 4226, or equivalent. Steady-state performance of electric power systems; steady-state electrical characteristics and equivalent circuit elements of static loads, rotating machines, transformers, and transmission circuits; steady-state circuit analysis of the power system network with the aid of the network analyzer; control and regulation of the power system to maintain normal operating conditions; use of digital and analogue computing devices.

4352. *POWER SYSTEMS II.* Credit 3 hrs. Spring. 2. Lect.-Rec. 1 Lab.-Comp. Prereq., 4114, 4226 and 4351, or equivalent. Transient analysis of electric power systems, especially the transients of electromagnetic quantities; characteristics of rotating machines; systems of components used in power system analysis; justification of quasi-steady-state analysis; use of a-c network analyzers, and electronic differential analyzers in computation.

4353. *POWER SYSTEMS III.* Credit 3 hrs. Fall. 2 Lect.-Rec. 1 Lab.-Comp. Prereq., 4351, and 4352, or equivalent. Electromechanical transients of power systems; protective schemes against abnormal operation of power systems; large-amplitude, and the small-amplitude swing or oscillation of the synchronous machine rotors; analytical methods in the understanding of the physical phenomena; analysis of protection and control schemes of the power system during abnormal operation.

4371. *HIGH-VOLTAGE PHENOMENA.* Credit 3 hrs. Spring. Prereq., 4351. The study of problems of the normal operation of power systems at very high voltages, of the abnormal conditions imposed by lightning, of the methods employed to assure proper operation of power systems and apparatus under high-voltage conditions, and of the devices available for laboratory testing of equipment under actual or simulated conditions.

RADIO AND COMMUNICATION

4501. *RADIO AND COMMUNICATION SEMINAR.* Credit 1 to 3 hrs. Fall and

spring. Primarily for graduate students. Reading and discussion of technical papers and publications in the field of radio and communication.

4511. *RADIO AND COMMUNICATION THEORY I.* Credit 3 hrs. Fall. 3 Lect. Prereq., 4113, 4114, and 4123. Study of the transient and steady-state response of circuits; consideration of noise in communication systems; elements of information theory; illustrative examples from fields of television, radar, and computers.

4512. *RADIO AND COMMUNICATION THEORY II.* Credit 3 hrs. Spring. 2 Lect. 1 Comp. Prereq., 4113, 4123. A study of communication circuits with distributed constants and the production and propagation of electromagnetic radiation; transmission line theory and applications; impedance matching; ultra-high-frequency generation and transmission; electromagnetic theory; propagation phenomena; antenna characteristics and radiation.

4516, 4517. *RADIO AND COMMUNICATION LABORATORY.* Credit 3 hrs. each. Fall and spring respectively. Either or both may be taken. 1 Rec. 1 Lab. Prereq., 4113 and 4123. Choice of three to five different experiments from the field of electronic circuits, networks, transmission lines; wave guides, and antennas; experiments selected to meet individual needs.

4541. *APPLIED ACOUSTICS.* Credit 3 hrs. Fall. 2 Lect.-Rec. 1 Lab. Laboratory assignments to meet individual needs. Prereq., 4123. The laws of ideal gases, the thermodynamic properties of air, and the laws of the propagation of compressional waves; the transmission of sound through tubes, horns, and unbounded media; the design of sound sources, microphones, loudspeakers, and wax, lacquer, magnetic, and photographic recorders; reflection, absorption, and reverberation.

4551. *RADIO AIDS TO NAVIGATION.* Credit 2 hrs. Spring. 2 Lect.-Rec. Prereq., 4123. Long-wave and medium-wave direction finders and radio beacons; atmospheric effects and limitations on accuracy; medium-frequency pulsed transit-time systems and high-frequency return-signal systems, with application to long-range navigation and precision mapping; airport approach systems and traffic control.

ELECTRONICS AND MICROWAVES

4526. *ELECTRON DYNAMICS.* Credit 3 hrs. Fall. 2 Lect. 1 Lab. Prereq., Phys. 214 and 4122. Fundamental theory of low-frequency electron devices; emission; conformal mapping; particle dynamics; electronstatic and magnetic lenses; space charge phenomena; limitations at high frequencies; noise; thermoelectric conversion; motion of electrons and holes in metals and semiconductors; junction diodes and transistors.

4527. *MICROWAVE ELECTRONICS.* Credit 3 hrs. Spring. 2 Lect. 1 Lab. Prereq., 4565. Study of the theory of high-frequency electron devices. Electron-electromagnetic field interaction theory for diodes, klystrons, traveling-wave tubes, Carcinotrons, and magnetrons.

4529. *TRANSISTOR ELECTRONICS.* Credit 3 hrs. Fall. 2 Lect. 1 Lab. Prereq., Phys. 214 and 4123. Motion of electrons and holes in semiconductors; the physical basis of transistor action and semiconductor rectifiers; characteristics of semiconductor devices; application of semiconductor devices as active or passive elements in circuits for use as amplifiers, oscillators, modulators, switches, photoelectric devices, and other circuits.

4561. *MICROWAVE THEORY ANL TECHNIQUES.* Credit 3 hrs. Spring. 2 Lect. 1 Lab. Prereq., 4565. Normal modes in waveguides and cavities; power, energy, perturbation, and transformation relations in confined microwave fields in isotropic media; theory of and experiments with microwave circuits; introduction to fields and waves in plasmas and ferrites.

ELECTROMAGNETIC WAVES AND PROPAGATION

4565. *ELECTROMAGNETIC THEORY.* Credit 3 hrs. Fall. 3 Lect. Prereq., Phys. 123 and 4113. The foundations of electromagnetic theory required for study of radio wave propagation; reflection and refraction of plane waves; guided waves; simple obstacles in wave guides; angular spectra of plane waves; edge diffraction theory.

4566. *RADIO WAVES I.* Credit 3 hrs. Spring. 3 Lect. Prereq., 4565. Influence of the earth, lower atmosphere, and ionosphere on propagation of radio waves; the Sommerfeld theory; propagation in an ionized medium; reflection from the ionosphere at normal and oblique incidence; influence of the earth's magnetic field upon ionospheric propagation.

4567. *RADIO WAVES II.* Credit 3 hrs. Fall. 3 Lect. Prereq., 4566. Influence of the troposphere on radio wave propagation; dielectric properties of air and distributions of refractive index; propagation in standard and nonstandard atmospheres; diffraction around a spherical earth; inhomogeneities of refractive index; scattering.

4568. *ANTENNAS.* Credit 3 hrs. Spring. 3 Lect. Prereq., 4565. Theory of radiation and reception; directional characteristics; impedance; elementary theory of cylindrical antennas; Huygens' principle; aperture antennas; antenna thermodynamics.

4581. *MAGNETOHYDRODYNAMICAL PROCESSES IN THE SOLAR SYSTEM.* Credit 2 hrs. Fall. 2 Lect. Prereq., 4565 or Physics 225. Theories of solar phenomena—solar flares, prominences, coronal features; the interplanetary plasma—density, velocity, ionization, magnetic fields; cosmic ray effects associated with solar events—production and modulation; theories of magnetic disturbances, magnetic storms, aurorae, Van Allen radiation, and associated ionospheric effects.

NETWORK AND INFORMATION THEORY

4115. *PRINCIPLES OF NONLINEAR CIRCUITS.* Credit 3 hrs. Fall. 3 Lect. Prereq., 4114. Foundations of electrical nonlinear circuits; methods of nonlinear analysis such as graphical, piecewise linear approximations, nonlinear mechanics and topological aspects of phase spaces; fundamental concepts of pulse and control circuits with reference to radar, pulse communication, computers, and automatic control.

4563. *SIGNALS AND NOISE IN COMMUNICATION SYSTEMS.* Credit 3 hrs. Fall. 3 Lect. Prereq., 4123. Analysis of signals in the time and frequency domains; properties of generalized linear systems; the time and frequency response of idealized systems; sampling theory for band-limited signals; probability and noise statistics with applications to signal transmission and signal detection; power spectrum analysis applied to special nonlinear problems of detection; the fundamentals of noise suppression in broad-band systems with particular emphasis on time multiplex communication and data transmission systems.

4564. *TRANSMISSION OF INFORMATION.* Credit 3 hrs. Spring 3 Lect. Prereq., 4563. Mathematical description of the transmission of information based on statistical models; quantitative measure of information in discrete noise-free systems; discrete transmission in the presence of noise; maximum rate of transmission in a noisy channel; information gain in continuous transmission systems; information capacity of the noisy continuous channel; optimum receivers for the extraction of information from a noisy transmission; applications of information theory to the analysis of transmission rate in practical systems.

4571 *MODERN NETWORK ANALYSIS.* Credit 3 hrs. Fall. 3 Lect. Prereq., 4113. Mesh and nodal analysis; fundamentals of network topology; network functions in the complex frequency plane; energy functions; realizability criteria for passive one-

ports; introduction to the synthesis of passive one-ports and two-ports; introduction to Hilbert Transforms.

4572. *MODERN NETWORK SYNTHESIS.* Credit 3 hrs. Spring. 3 Lect. Prereq., 4571. Real-part sufficiency and related topics; the realization problem of driving-point and transfer functions, Darlington's theory; the Miyata method; Guillemin's zero-shifting technique; iterative and other "classical" procedures; the approximation problem—least square and Tschebyscheff sense—in the frequency domain; time-domain synthesis; correlation between frequency and time domains.

ILLUMINATION

4611. *INTRODUCTORY ILLUMINATION.* Credit 3 hrs. Fall. 2 Rec. 1 Lab.-Comp. Prereq., Phys. 124. Problems commonly encountered in illumination engineering and the methods of solution; sources of light; visual perception; light control, both spectral and directional; measurement of light sources and illumination; general illumination design; production and mixing of colors; architectural objectives.

4612. *ILLUMINATING ENGINEERING.* Credit 3 hrs. Spring. 2 Rec. 1 Lab.-Comp. Prereq., 4611. Computation of light-flux distribution and study of difficult lighting problems; emphasis on specialized rather than general lighting problems.

4615. *ILLUMINATION SEMINAR.* Credit 2 hrs. Fall. 1 two-hour period each week. Must be accompanied or preceded by 4611. Reports on selected topics of current interest in illuminating engineering.

CONTROL SYSTEMS AND COMPUTERS

4711. *FEEDBACK CONTROL SYSTEMS I.* Credit 3 hrs. Fall. 2 Lect. 1 Lab. Prereq., 4122, 4216, 4221. Principles of feedback control systems emphasizing analysis of performance from equations and transfer-function plots; Laplace transformations; error detecting devices; hydraulic devices; factors affecting errors, damping, and speed of response; criteria for stability.

4712. *FEEDBACK CONTROL SYSTEMS II.* Credit 3 hrs. Spring. 2 Lect. 1 Lab. Prereq., 4711. Synthesis of feedback control systems; prediction of performance from stability criteria and comparison with laboratory performance; relay control systems; consideration of nonlinearity.

4713. *FEEDBACK CONTROL SYSTEMS SEMINAR.* Credit 2 or 3 hrs. 1 two-hour period and 1 optional lab-comp., Prereq., 4712. Reports on selected topics in servomechanisms; signal flow diagrams; nonlinear effects on analysis and performance; sampled data systems; statistical considerations; analog computer studies of limiting, backlash, dead zone, and sampled data systems.

4411. *ELECTRONIC CONTROL EQUIPMENT.* Credit 3 hrs. Fall. 2 Lect. 1 Lab. Prereq., 4123. Principles of electronic instrumentation and electronic control systems; methods of utilizing a stimulus in the form of heat, light, sound, or mechanical motion; industrial circuits including timing circuits, photoelectric controls, motor controls, welder controls, voltage regulators, frequency-varying and frequency-discriminating circuits; theory of magnetic amplifiers and their use as control circuit components.

4415. *ADVANCED ELECTRONIC CONTROLS.* Credit 3 hrs. Spring. 2 Lect. 1 Lab.-Comp. Prereq., 4411. An advanced study of the theory, design, and characteristics of selected electronic units.

4421. *ELECTRONIC POWER CONVERTERS.* Credit 3 hrs. Spring. 2 Lect. 1 Lab.-Comp. Prereq., 4411. Study of oscillators, mercury-pool rectifiers, and inverters

in power sizes covering practical circuits, complete laboratory tests, and comprehensive mathematical treatments.

4810. *ANALOG COMPUTATION.* Credit 3 hrs. Fall. 2 Lect. 1 Lab. Prereq., 4114 or Differential Equations. Does not require background in electronics. Basic concepts and principles of analog computation; use of the electronic analog computer to solve the basic mathematical models; simulation of complex physical systems; scaling and programing; laboratory work involves solution of problems on general-purpose computers.

4820. *SWITCHING THEORY AND DIGITAL COMPUTERS.* Credit 3 hrs. Spring. 2 Lect. 1 Lab. An introduction to the theory and design of switching circuits; detailed consideration of switching algebra and its application to design of digital computers; combinatorial systems; sequential systems; Boolean Matrix theory; number representation and codes; basic properties of digital computers; programing of general-purpose computers.

COURSES FOR OTHER ENGINEERING CURRICULA

4931. *ELECTRICAL ENGINEERING.* Credit 3 hrs. Fall and spring. 1 Lect. 1 Rec. 1 Comp. Prereq., Math. 163, Mech. 1132 or 1152. An elementary study of direct-current electric circuits; the concepts of resistance, inductance, and capacitance; magnetic circuits; single-phase and three-phase alternating-current circuits; instruments and techniques appropriate for making measurements in all such circuits.

4932. *ELECTRICAL ENGINEERING.* Credit 3 hrs. Fall and spring. 1 Lect. 1 Rec. 1 Lab.-Comp. Prereq., 4931. D-c generators and motors; motor starters and controllers; transformers; induction motors; synchronous machines; a-c single-phase motors; d-c and a-c selsyn units.

4933. *ELECTRICAL ENGINEERING.* Credit 3 hrs. Fall and spring. 1 Lect. 1 Rec. 1 Lab.-Comp. Prereq., 4932. The characteristics and applications of the various commonly used electron tubes; rectifiers; amplifiers; oscillators; electronic control and instrumentation.

4934. *PRINCIPLES OF AUTOMATIC CONTROL.* Credit 3 hrs. Spring. 1 Lect. 1 Rec. 1 Lab. Prereq., 4933. The mathematics of automatic control as exemplified in servo devices, with analysis of electrical, mechanical, and hydraulic applications; problems of electrical instrumentation in automatically controlled operations and processes.

4983. *BASIC ELECTRICAL ENGINEERING.* Credit 4 hrs. Spring. 1 Lect. 2 Rec. 1 Comp. Prereq., Math. 163, Phys. 123. Capacitors; simple electrical transients; direct-current and alternating-current circuits; magnetic circuits including permanent magnetic material.

4991. *ELECTRONIC CIRCUITS.* Credit 3 hrs. Fall. 3 Lect. For graduate students majoring in an engineering field other than electrical. Alternating-current circuits; characteristics of high-vacuum tubes and transistors; small-signal and large-signal amplifiers; feedback and oscillators; modulation and demodulation; simple wave-shaping circuits.

CHEMICAL ENGINEERING

5000. *ORIENTATION.* No credit. Fall and spring. 1 Lect. Both terms required of all freshmen.

5101, 5102. *INTRODUCTORY CHEMICAL ENGINEERING.* Credit 2 hrs. Fall and spring. 2 Lect. Prereq., Chemistry 113, 114. An introduction to the processes and calculations of chemical engineering.

Dedicated in 1941, Olin Hall is the home of the School of Chemical and Metallurgical Engineering.

5103, 5104. *CHEMICAL ENGINEERING THERMODYNAMICS.* Credit 3 hrs. Fall and spring. 3 Lect. Prereq., Chemistry 403, 404. A study of the first and second laws with application to batch and flow processes. Physical and thermodynamic properties. Availability; free energy; chemical equilibrium. Application to gas compression; process steam; power generation; adiabatic reactors; and chemical process development.

5106. *REACTION KINETICS AND REACTOR DESIGN.* Credit 2 hrs. Spring. 2 Lect. Prereq., 5104. A study of chemical reaction kinetics and principles of reactor design for chemical processes.

5108. *APPLIED PHYSICAL CHEMISTRY.* Credit 2 hrs. Spring. 2 Rec. Prereq., Chemistry 404. Engineering properties of real gases, liquids, and solutions including colloids. Theory of catalysis. Discussion and problems on prediction of transport properties such as viscosity and diffusion coefficients. Emphasis is on accurate qualitative concepts of molecular theory and intermolecular forces. Given in alternate years.

5110. *ELEMENTARY CHEMICAL ENGINEERING.* Credit 3 hrs. Spring. Prereq., Chemistry 102 or 106. Physics 104, three years of high school mathematics. Primarily for students in agriculture or nutrition. Not open to students in chemical engineering. Lectures and problems on energy and material balances, evaporation, heat transfer, fluid flow, filtration, etc.

5203, 5204. *CHEMICAL PROCESSES.* Credit 2 hrs. Fall and spring. 2 Lect. An analysis of important chemical processes and industries. Fall term, inorganic chemical processes; spring term, organic chemical processes.

5205. *ADVANCED CHEMICAL PROCESSES.* Credit 2 hrs. Fall. A course for graduate students on recent advances in chemical processes.

5303, 5404. *UNIT OPERATIONS.* Credit 3 hrs. Fall and spring. 3 Lect. Prereq. or parallel, Chemistry 403 and Engineering 5203 and 5204. A critical discussion of the unit operations of chemical engineering.

5353, 5354. *UNIT OPERATIONS LABORATORY.* Credit 3 hrs. Fall and spring. Prereq., 5303, 5304.

5503, 5504. *CHEMICAL ENGINEERING COMPUTATIONS.* Credit 2 hrs. Fall and spring. Two class periods. Prereq. or parallel, 5303 and 5304 or equivalent. Lectures and advanced problems in fluid flow and heat transfer; heterogeneous equilibrium; distillation; gas absorption; and extraction. A selected number of the less conventional operations are also considered.

5505. *ADVANCED HEAT TRANSFER.* Credit 2 hrs. Spring. Prereq., 5303–4 or equivalent. Advanced topics in heat transfer. Heat transfer under unsteady-state conditions; numerical approximation methods; analogies among heat, mass, and momentum transfer; heat transfer to liquid metals; simultaneous heat and mass transfer, etc. Primarily for graduate students.

5506. *DIFFUSION OPERATIONS.* Credit 3 hrs. Fall. 3 class periods. Prereq., 5503, 5504, or equivalent. Primarily for graduate students. Advanced topics in distillation; gas absorption; liquid-liquid extraction; and drying.

5508, 5509. *APPLIED MATHEMATICS IN CHEMICAL ENGINEERING.* Credit 3 hrs. Fall and spring. 3 Lect. Prereq., 5304. Treatment and interpretation of data. Ordinary differential equations. Series and numerical solutions. Partial differential equations. Fourier series; Bessel functions; Laplace transforms. Calculus of finite differences. Numerical solutions to partial differential equations. Applications to heat transfer, mass transfer, distillation, gas absorption, reaction kinetics, and catalysis.

5605, 5606, 5607, 5608. *DESIGN PROJECT.* Credit 2 hrs. Fall and spring. Individual problems in the design of chemical processes and plants. Estimation of costs of construction and operation, variation of costs and profits with production, etc.

5609. *OPERATIONS DESIGN METHODS.* Credit 2 hrs. Fall. 2 Lect. Description and discussion of chemical process equipment for physical operations, such as mixing, diffusional separations, mechanical separations, heat transfer, size reduction, etc. Emphasis is placed on evaluation of alternative methods of achieving a desired objective and on selection and arrangement of equipment for most economical operation.

5610. *DESIGN OF PROCESS PLANTS.* Credit 4 hrs. Spring term. Development of the major steps in the design of facilities to make chemical products and intermediates. Market surveys and detailed cost estimation are included. The design covers process equipment and piping, services and utilities, instrumentation and control, plans and elevations, safety precautions, and operating procedures.

5701. *PLANT INSPECTIONS.* Credit 1 hr. Spring. A series of supervised inspection trips to manufacturing plants representing various chemical engineering industries.

5711. *LIBRARY USE AND PATENT LAW.* Credit 2 hrs. Fall. 2 Lect. The effective use of the technical literature; literature searches, abstracts and bibliographies. Patent law: inventiveness and patentability; revised patent statutes; abandonment; rights; infringement; licensing arrangements; case studies.

5741. *PETROLEUM REFINING.* Credit 3 hrs. Spring. 3 Lect. Prereq., 5304. Processes employed in petroleum refining.

5742. *POLYMERIC MATERIALS.* Credit 3 hrs. Fall. Prereq., Chemistry 404. Polymerization reactions, manufacture and properties of synthetic resins, fibers, plastics, and rubbers.

5743. *ADVANCED POLYMERIC MATERIALS.* Credit 2 hrs. Spring. Prereq., 5742. Special topics involving rubbers, fibers, and plastics.

5746. *CHEMICAL ENGINEERING ECONOMICS.* Credit 3 hrs. Fall. 3 Lect. Prereq., 5304, or special permission. The economic aspects of research, development, manufacturing, and sales in the chemical industries.

5747. *PROCESS CONTROL.* Credit 3 hrs. Spring. 2 Lect. 1 Lab. Prereq., 5304. Frequency response and transient response of process equipment. Brief description of control instruments. Design of processes and selection of controllers for desired dynamic behavior. (Not given in spring of 1960.)

5748. *FERMENTATION ENGINEERING.* Credit 2 hrs. Spring. 2 Lect. Prereq., or parallel courses, Chemistry 404 or 408, and any course in microbiology. An advanced discussion of fermentation as a unit process. Topics include sterilization, aeration, agitation, and continuous fermentation. Given in alternate years.

5749. *INDUSTRIAL MICROORGANISMS.* Credit 1 hr. Fall. 1 Lect. Prereq., organic chemistry and physical chemistry. A brief introductory course in microbiology for students with a good background in chemistry. Text: Clifton's *Introduction to the Bacteria.*

5752. *POLYMERIC MATERIALS LABORATORY.* Credit 1 hr. Spring. 1 Lab. Prereq., 5742. Experiments in the formation, characterization, fabrication, and testing of polymers.

5760. *NUCLEAR AND REACTOR ENGINEERING.* Credit 2 hrs. Fall. 2 Lect. Fuel processing and isotope separation, radioactive waste disposal, fuel cycles, radiation damage, biological effects and hazards, shielding, power reactors.

5851. *CHEMICAL MICROSCOPY.* Credit 3 hrs. Either term. 1 Lect. 2 Lab. Prereq., or parallel courses, Chemistry 403, 404, or 407, 408 and Physics 123, 124, or special permission. Microscopical examination of chemical and technical materials, processes, and products. Measurements, particle size determination, analyses of mixtures, crystallization, phase changes and colloidal phenomena, lens systems and photomicrography.

5853. *MICROSCOPICAL QUALITATIVE ANALYSIS (INORGANIC).* Credit 2 hrs. or more. Either term. Prereq., 5851. Laboratory periods to be arranged. Laboratory practice in the analysis of inorganic substances containing the more common elements.

5859. *ADVANCED CHEMICAL MICROSCOPY.* Credit 1 hr. or more. Either term. Prereq., 5851 and special permission. Laboratory practice in special methods and special applications of chemical microscopy.

5900. *SEMINAR.* Credit 1 hr. Fall and spring. General chemical engineering seminar required of all graduate students majoring in the field of chemical engineering.

5953, 5954. *RESEARCH PROJECT.* Credit 2 hrs.; additional credit by special permission. Fall and spring. Prereq., 5304. Research on an original problem in chemical engineering.

5955, 5956. *SPECIAL PROJECTS IN CHEMICAL ENGINEERING.* Credit variable. Either term. Prereq., 5954. Research or studies on special problems in chemical engineering.

METALLURGICAL ENGINEERING

6000–6001. *ORIENTATION.* No credit. Fall and spring. 1 Lect. Both terms required of all freshmen.

6110. *CASTING, WORKING, AND WELDING OF METALS.* Credit 2 hrs. Either term. 1 Lect. 1 Lab. An elementary course covering the important industrial processes used in the casting, hot working, cold forming, and welding of metals. The utilization of metallurgical processes in other branches of engineering is stressed.

6112. *METALS TECHNOLOGY.* Credit 2 hrs. Spring. 2 Lect. Prereq., 6110, 1243. An advanced course for students in mechanical engineering covering the mechanical and metallurgical factors affecting service behavior of metals under static and dynamic loading. Subjects covered include failure criteria, brittle fracture, creep, embrittlement, fatigue, and corrosion.

6201. *PRODUCTION OF METALS.* Credit 3 hrs. Fall. 3 Lect. Crushing, grinding, and beneficiation of ores. Reduction and refining of metals. Production of commercial metals and alloys, including a detailed study of steel production.

6202. *THE NATURE AND UTILIZATION OF METALS.* Credit 3 hrs. Spring. 2 Lect., 1 Rec. An introduction to the nature of metals and alloys, their properties and engineering behavior, to provide a basis for further intensive study of materials science and application. In addition to a fundamental treatment and systematic correlation of the properties of metallic materials, the physics, chemistry, and technology of melting, solidification, plastic deformation, heat treatment and powder metallurgy are considered. Relationships between the internal structure, the mechanical and physical properties, and the engineering applications of materials are stressed.

6251. *METALLURGICAL ENGINEERING LABORATORY.* Credit 1 hr. Fall. 1 Lab. period. Experiments designed to illustrate unit processes used in winning of metals, and in production of useful alloys.

6252. *METALLURGICAL ENGINEERING LABORATORY.* Credit 2 hrs. Spring. 1 Lect., 1 Lab. Concurrently with 6202. Laboratory experiments exemplifying methods of metallurgical examination, including several of the methods for determining mechanical properties of materials. Processes for melting and casting metals, hot working and cold forming metals, welding and heat treating ferrous and nonferrous alloys are considered. The laboratory procedures and experiments will be related to the concurrent material in Course 6202. Instruction and practice in report writing is included.

6255, 6256. *MATERIALS OF CONSTRUCTION.* Credit 3 hrs. each term. 3 Lect. Prereq. or parallel courses, Physical Chemistry 403, 404. An introductory presentation of the nature, properties, treatment, and applications of the more important metals and alloys, including extractive and physical metallurgy and behavior under service conditions. Nonmetallic materials, including refractories, cement, protective coatings, and plastics, are also discussed.

6301. *PRINCIPLES OF METALLURGICAL ENGINEERING.* Credit 3 hrs. Fall. 3 Lect. Prereq. 6201. Discussion and calculations concerning fuels, combustion, fluid flow, heat flow, roasting and sintering, gas cleaning, and application of thermochemical data to metallurgical processes.

6353. *INTRODUCTORY METALLOGRAPHY.* Credit 3 hrs. Spring. 1 Lect. 2 Lab. Prereq. 6202, 6255, or permission of the instructor. Microstructures of alloys, as related to composition, thermal history, and physical properties. Preparation of specimens; principles and use of metallographic microscopes.

6403. *METALLURGICAL THERMODYNAMICS.* Credit 3 hrs. Fall. 3 Lect. Prereq. Chem. 404. A discussion of homogeneous equilibria with emphasis upon metallic liquid and solid solutions. Subjects considered include the first and second laws, partial and integral molar properties, and experimental methods. The theory of disorder in crystals is introduced.

6404. *METALLURGICAL THERMODYNAMICS.* Credit 3 hrs. Spring. 3 Lect. A discussion of heterogeneous equilibrium utilizing systems of metallurgical interest as examples. Topics considered include phase rule, zone purification, furnace atmospheres, refining, and iron-carbon alloys.

6411, 6412. *PHYSICAL METALLURGY.* Credit 3 hrs. Fall and spring. Prereq., 6353. Detailed discussion of plastic deformation, recrystallization and grain growth, diffusion in alloys, precipitation from solid solution, and transformation mechanisms in heat treatment.

6415. *PRINCIPLES OF MATERIALS PROCESSING.* Credit 3 hrs. Fall. 2 Lect., 1 Rec. Prereq., 6202, 6353. An advanced course relating basic and applied sciences to materials processing and technology. Includes a critical study of selected casting, metal forming and working, welding, and powder metallurgy processes. Emphasis is placed on scientific and engineering principles rather than industrial techniques: alloying, heat transfer, and solidification in foundry operations; criteria for plastic flow in metal working processes; distortion, residual stress and heat effects in welding; compacting and sintering in powder metallurgy; chip formation and tool forces in machining.

6452. *EXPERIMENTAL PHYSICAL METALLURGY.* Credit 3 hrs. Fall. Labs. with conferences. Theory and metallurgical application of X-ray diffraction, and experiments to illustrate the important phenomena of physical metallurgy and techniques for their investigation. Determination of crystal structure, lattice parameters, preferred orientations, single crystal orientation, order-disorder transformations by X-ray diffraction techniques. Special problems in X-ray metallography.

6471. *PLANT INSPECTION.* Credit 1 hr. Spring. A series of supervised inspection trips to manufacturing plants representing various metallurgical engineering industries. Each student is required to submit a comprehensive report.

6503. *SERVICE BEHAVIOR OF METALS.* Credit 3 hrs. Fall. 3 class periods. Prereq., 6412. Metallurgical and mechanical factors governing the selection of metals for various services. Analysis of service requirements, and the selection and fabrication of metals to fulfill such requirements; analysis of service failures of metals and remedies for such failures; and study of the merits and limitations of materials applications in existing products and equipment.

6504. *UNIT PROCESSES IN METALLURGY.* Credit 3 hrs. Fall. 1 Lect. and 1 Lab. period with reports. Prereq., 6201, 6251, 6301. Experimental study of important processes in metallurgy, including generation of furnace atmospheres, furnace design and performance, determination of rates of heating and cooling, and electrochemical operations. Reports based on the experimental data, discussing principles involved in the operations, are an important part of the course.

6506. *METALLURGICAL DESIGN.* Credit 2 hrs. Spring. Prereq., 6503. A seminar course using a modified case-history approach to problems and current developments in metallurgical engineering.

6553, 6554. *SENIOR PROJECT.* Credit 2 hrs. Fall and spring. Prereq., research on an original problem in metallurgical engineering.

6620. *ADVANCED FOUNDRY ENGINEERING.* Credit 3 hrs. Fall. 3 class periods including special laboratory studies. Prereq., critical study of foundry technology and the metallurgical features of cast metals. Laboratory investigation of special foundry processes and procedures.

6623. *STEEL MILL PRODUCTS.* Credit 2 hrs. Fall. 2 Lect. Prereq., permission of the instructor. Engineering, scientific, and economic factors involved in the production of iron and steel, including alloy steels. The production of structural sections, plate, strip, tin plate, and other steel mill products.

6624. *KINETICS OF METALLURGICAL REACTIONS.* Credit 3 hrs. 3 Lect. Prereq., 6403. Consideration is given to kinetics of gases, empirical treatment of reaction rates, Arrhenius equation, transition state theory, diffusion, and nucleation theory. Applications include vacuum furnaces, radioisotopes, corrosion, recrystallization and grain growth in metals, solidification, and phase transformations in solids.

6641. *CERAMICS.* Credit 2 hrs. Fall. 2 Lect. Prereq., permission of the instructor. Physical chemistry, structure, and behavior of ceramic materials in technology.

6651. *ALLOY STEELS.* Credit 2 hrs. Lect. Fall. Prereq., permission of the instructor. Study of the basic effects of alloying on the structure and properties of steels, and the application of this knowledge to the design of modern high-strength, stainless, or heat-resistant steels and of steels for tools and dies.

6661. *METALS AT HIGH TEMPERATURES.* Credit 2 hrs. Lect. Fall. Prereq., permission of the instructor. Evaluation and application of metals for use at service temperatures. Emphasis is placed on nature of creep flow and fracture at elevated temperatures. Attention is also paid to scaling, metallurgical instability, and various physical properties.

6671. *PRINCIPLES OF POWDER METALLURGY.* Credit 3 hrs. Fall. 2 Lect. and one 2½-hour lab. each week. Following brief consideration of industrial powder-metallurgy equipment, including dies, presses, and sintering furnaces, and industrial applications such as porous products, permanent magnets, refractory metals, cemented carbides, cermets, etc., the theory of powder metallurgy is treated critically. Emphasis is on the theories of compacting and sintering, diffusional processes, and

surface chemistry. The theories, applications, and limitations of hot pressing are examined critically. Laboratory experimentation is primarily concerned with fundamental investigation of compacting, bonding, sintering, hot pressing, infiltration of porous networks, etc. Laboratory studies of surface chemistry and surface activation are included.

6872. *NUCLEAR MATERIALS TECHNOLOGY.* Credit 2 hrs. Spring. 2 Lect. Production of fissile, source materials, and other materials used in nuclear reactors. Behavior of materials in nuclear reactors, including deterioration by corrosion and radiation. Problems involved with respect to fuel elements. Fabrication of reactor and reactor components.

6960. *SEMINAR IN PHYSICAL METALLURGY.* For graduate students. Fall and spring. Hours to be arranged. Diffusion, nucleation and growth, precipitation from solid solution, eutectoid decomposition, diffusionless transformations, recovery, recrystallization and grain growth, order-disorder, radiation effects.

6970. *SEMINAR IN PHYSICAL CHEMISTRY OF METALS.* For graduate students. Fall and spring. Hours to be arranged. Physical chemistry of metallurgical reactions with emphasis on reduction and refining, gas-liquid metal-slag reactions, thermodynamics of phase equilibria and interfaces, phase stability, electrochemistry, oxidation and corrosion.

AERONAUTICAL ENGINEERING

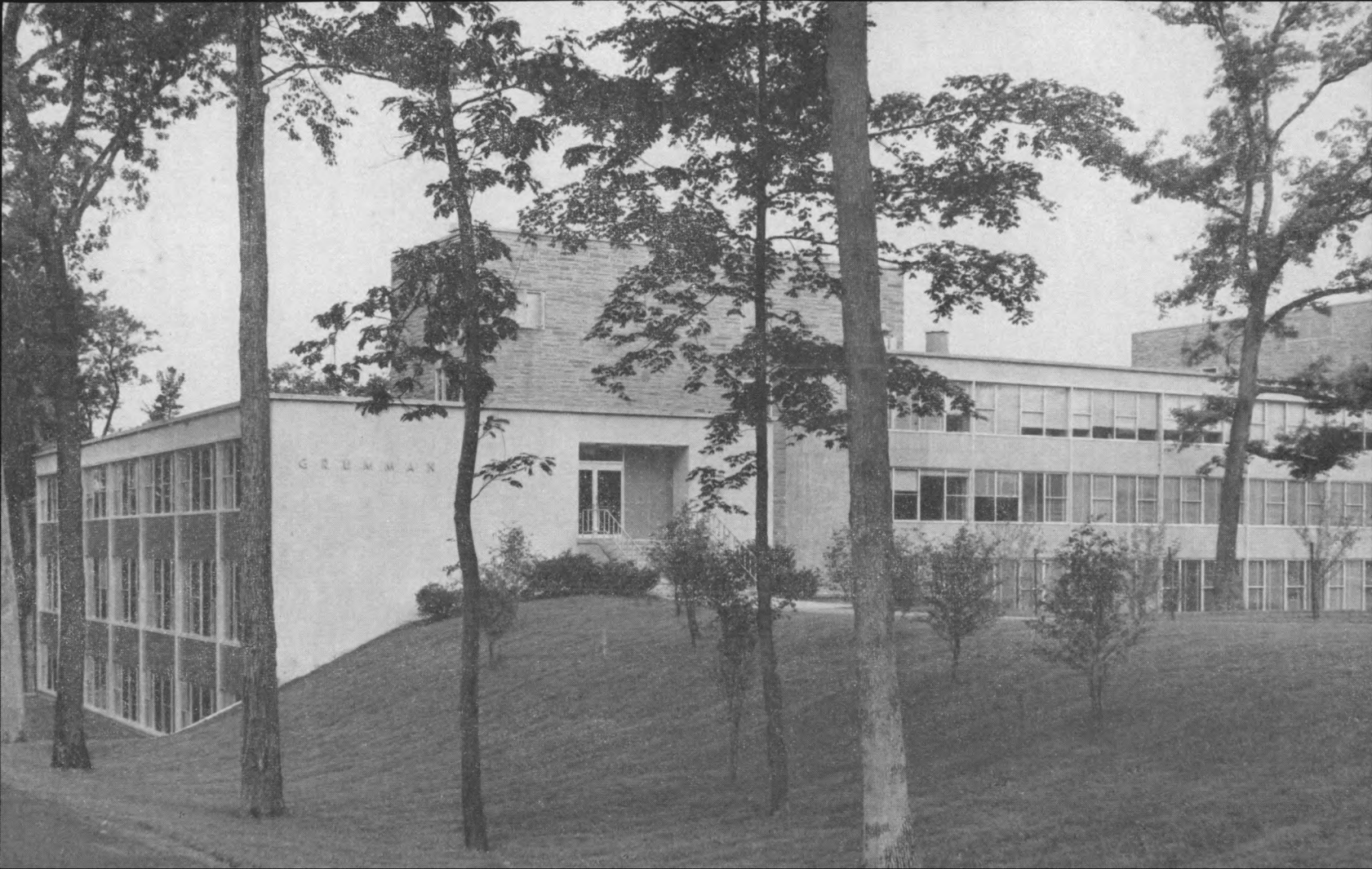
7001. *INTRODUCTION TO AERONAUTICAL ENGINEERING.* Credit 2 hrs. Given as required. Prereq., engineering mechanics. An introductory course for undergraduate students in all branches of engineering. Emphasis on aircraft mechanics; aerodynamic forces; airplane and missile performance, airplane stability and control. Missile and satellite trajectories.

7101. *MECHANICS OF AIRPLANES AND MISSILES.* Credit 3 hrs. Fall. Prereq., engineering mechanics. Physics of the atmosphere, properties of gases and fluids; similarity laws. Inviscid incompressible flow; momentum methods; vortices; introduction to airfoil and wing theory. Basic properties of compressible flow at subsonic, transonic, and supersonic speeds. Introduction to the methods of viscous flow theory; viscous drag; experimental methods. Estimation of airplane and missile performance. Elements of stability.

7102. *MECHANICS OF AIRPLANES AND MISSILES.* Credit 3 hrs. Spring. Prereq., 7101. Static longitudinal stability, controls-fixed and controls-free; power effects; control forces. Dynamics of longitudinal motion; phugoid motion; stability, estimation of stability derivative. General rigid body motion and accelerating coordinate systems; lateral stability; large lateral motion; gyroscopic effects. Response problems. Automatic control. Introduction to "very high" speed flight, hypersonic glider, planetary motion, rocket acceleration.

7203. *GASDYNAMICS I.* Credit 3 hrs. Fall. Prereq., engineering thermodynamics. Cycle thermodynamics; the gas-turbine process. Thermodynamics of flow. Cycle and analysis of turbojets, ramjet, turboprop, ducted-fan, afterburner, etc. Heat transfer by force convection at high speeds; gas properties. Reymonds' analogy. One-dimensional steady flow of a perfect gas with heat addition, shock waves, etc. Elements of the jet-propulsion engine; combustion chamber; aerodynamic design of compressors and turbines. Rockets.

7204. *GASDYNAMICS II.* Credit 3 hrs. Spring. Prereq., 7203 or 8121. Wave-propogation phenomena, method of characteristics for 2-dimensional and axisym


GRUMMAN

metric supersonic steady flow and unsteady channel flow. Experimental methods. Hypersonic flow phenomena, flow of real gases, and magneto-hydrodynamics.

7206. *INTRODUCTION TO MAGNETOHYDRODYNAMICS.* Credit 2 hrs. Prereq., 7203. Review of electrodynamics, conduction of electricity in gases, equations of motion of magnetohydrodynamics, solutions for special cases and under various approximations, magnetohydrodynamic waves, phenomena in rarefied gases.

7301. *THEORETICAL AERONYNAMICS I.* Credit 3 hrs. Six hours a week during the first half of the fall term. Prereq., differential equations, intermediate mechanics or introduction to theoretical physics. Introduction to theoretical hydrodynamics. Ideal fluids. The boundary-value problems of steady and nonsteady two- and three-dimensional potential flows with special attention to flows produced by the motion of solid bodies. Vector methods and complex variable are used extensively.

7302. *THEORETICAL AERODYNAMICS II.* Credit 3 hrs. Spring. Prereq., 7301, 7303. Wing theory; thin-airfoil theory, two-dimensional airfoil theory. Prandtl wing theory, lifting surfaces, general multiple theory, nonstationary wing theory. Correction for compressibility (linearized theory). Wing theory for supersonic speeds; source and sink methods and extensions, conical-flow methods, nonstationary cases.

7303. *THEORETICAL AERODYNAMICS III.* Credit 3 hrs. Six hours a week during the second half of the fall term. Prereq., 7204, 7301. The aerodynamics of compressible fluids; equations of motion, small-perturbation theory (subsonics and supersonic); Janzen-Reyleigh theory, the hodograph methods, the limiting line, the method of characteristics, Prandtl-Meyer flow, hypersonic flow.

7304. *THEORETICAL AERONYNAMICS IV.* Credit 3 hrs. Spring. Prereq., 7301. The aerodynamics of viscous fluids; the boundary layer, heat transfer, fundamentals of boundary-layer stability. Turbulence, the fundamentals of isotropic turbulence. Experimental methods.

7306. *THEORY OF PROPELLERS AND ROTORS.* Credit 1 hr. Spring. Prereq., 7101 or equivalent. Momentum and blade-element theories. Glauert-Betz theory of lightly loaded propellers and other theories; two-dimensional cascades; application to compressors; fans and turbines; application to helicopters.

7403. *AIRCRAFT DESIGN.* Credit 1 hr. Fall. Orientation; the airplane and its components; the philosophy of airplane and missile design; aircraft materials and processes. Rocket and missile performance. Load factors. Guidance. Trajectories.

7404. *AIRCRAFT DESIGN.* Credit 1 hr. Spring. Prereq., 7403. Orientation (continued).

7405. *AEROELASTIC PROBLEMS.* Credit 3 hrs. Fall. Prereq., 7101 and strength of materials. Background, influence coefficients and functions, generalized coordinates, etc. Some civil and mechanical engineering aeroelastic problems. "Classical" static and dynamic stability and response problems, divergence, control reversal, torsion-flexure flutter, etc. General formulation, functional diagrams and operators. Special topics, panel flutter, gust loading, piston theory, etc.

7801. *RESEARCH IN AERONAUTICAL ENGINEERING.* (Credit to be arranged.) Prereq., admission to the Graduate School of Aeronautical Engineering and approval of the Director. Independent research in a field of aeronautical science. Such research must be under the guidance of a member of the staff and must be of a scientific character.

7901. *AERONAUTICAL ENGINEERING COLLOQUIUM.* Credit 1 hr. Prereq., admission to the Graduate School of Aeronautical Engineering. Lectures by staff members, graduate students, personnel of Cornell Aeronautical Laboratory, and

Grumman Hall, completed in 1959, houses the Graduate School of Aeronautical Engineering.

visiting scientists on topics of interest in aeronautical science, especially in connection with new research.

7902. *ADVANCED SEMINAR IN AERONAUTICS.* Credit 2 hrs. Prereq., approval of the Director.

ENGINEERING PHYSICS

8051 and 8052. *PROJECT.* Terms 9 and 10. Credit 3 hrs. Fall and spring. Informal study under direction of a member of the University staff. The objective is to develop self-reliance and initiative, as well as to gain experience with methods of attack and with over-all planning, in the carrying out of a special problem related to the student's field of interest. The choice of a problem is to be made by the student in consultation with members of the staff.

8090. *INFORMAL STUDY IN ENGINEERING PHYSICS.* Fall or spring. Laboratory or theoretical work in any branch of engineering physics under the direction of a member of the staff. Hours to be arranged.

8121–8122. *CLASSICAL THERMODYNAMICS.* Credit 3 hrs. Through the year. 3 Rec. Primarily for candidates for the degree of Bachelor of Engineering Physics. Introduction to classical thermodynamics, kinetic theory of gases, and statistical mechanics. Application to physical and engineering problems.

8131. *MECHANICS OF CONTINUA.* Credit 3 hrs. Spring. 3 Lect. Prereq., Math. 616, 622 or permission of the instructor. Stress and strain tensors; fundamental equations of motion in continuous media; generalized equation of state; applications to special topics of general and engineering interest in elasticity, wave propagation, vibration, imcompressible and compressible fluids, viscous flow, etc.

8252. *SELECTED TOPICS IN PHYSICS OF ENGINEERING MATERIALS.* Credit 3 hrs. Fall term. Primarily for fifth year students in engineering physics; others with consent of instructor. Seminar-type discussion of a number of special topics in the field of engineering materials, such as plastic and rheological properties; dielectric and magnetic behavior; semiconductors; radiation damage, etc. Emphasis is given to the interpretation of the phenomena in light of modern theories in physics of solids and liquids and their impact on the engineering applications; current literature is included in the assignments.

8262. *PHYSICS OF SOLID SURFACES.* Credit 3 hrs. Spring. 1 Lect. and 1 Seminar. Primarily for graduate and fifth year students in applied physics and engineering. An introductory outline to recent advances in theories of crystalline surfaces and applications to selected topics in physics, chemistry, and metallurgy.

8301. *INTRODUCTION TO ATOMIC AND NUCLEAR PHYSICS.* Credit 3 hrs. Fall. 3 Lect. Prereq., Physics 124 or 126 or 128, and calculus through differential equations. Primarily for students in nuclear engineering. Concepts of atomic structure of matter; fundamentals of quantum theory and applications to structure of atoms, molecules, and nuclei. Concepts of nuclear reactions and their relation to nuclear reactor problems, including the chain reaction.

8311. *NUCLEAR AND REACTOR PHYSICS.* Credit 3 hrs. Spring. 3 Lect. Prereq., Physics 214 or 243. Nuclear particles, nuclear structure, nuclear reactions; characteristics of particle accelerators; properties of neutrons, interactions of neutrons with matter, nuclear fission; elementary reactor theory, types of reactors, reactor design problems; instruments for particle detection and reactor control.

8312. *INTERMEDIATE REACTOR THEORY.* Credit 3 hrs. Fall. 3 Lect. Continuation and enlargement of 8311, with greater emphasis upon theoretical aspects of the subject. Neutron slowing down theory; age theory, multigroup theory, and

machine methods for computing flux and mass; heterogeneous reactors; reactor dynamics, control, and lifetime.

8313. *ADVANCED REACTOR THEORY.* Credit 3 hrs. Spring. 3 Lect. Preceq., 8312 and Math. 616 or 622. Approximation methods for reactor calculations; transport theory; general theory of chain reacting systems. Selected topics such as flat flux reactors, kinetics of circulating fuel reactors, etc.

8321. *PRINCIPLES OF THERMONUCLEAR POWER.* Credit 2 hrs. Fall. 2 Lect. Prereq., 8311 or Physics 214 or Physics 244. An introductory course concerned primarily with physical problems involved in current thermonuclear research. Topics included are cross-sections of fusion reactions; theory of binary reactions; radiation processes; microscopic processes in plasmas; magnetohydrodynamics; problems of plasma confinement; present concepts of thermonuclear power reactors.

8351. *NUCLEAR MEASUREMENTS LABORATORY.* Credit 3 hrs. Either term. Two 2½ hr. afternoon periods. Pre- or co-req., 8311. Some twenty-five different experiments are available in the fields of nuclear and reactor physics and engineering. Among these are experiments in nuclear radiation detection and absorption; in properties of radiation detectors and specialized electronic circuits used in counting and reactor control; in interactions of neutrons with matter, especially moderation, diffusion, absorption, and scattering; in chemical separations and in casting and metallurgical examination of uranium. Experiments on a subcritical reactor are included. The student is expected to perform eight to ten experiments, selected to meet his needs. Some stress is laid on independent work by the student. May be elected more than once by students desiring broader or more advanced laboratory experience.

8352. *ADVANCED NUCLEAR MEASUREMENTS LABORATORY.* Credit 3 hrs. Either term. Two 2½ hour afternoon periods. Prereq., 8351. A continuation of 8351 for students desiring advanced laboratory experience.

8512. *ELECTRON MICROSCOPY.* Credit 3 hrs. Spring. Prereq., permission of the instructor. Lect. Lab. Hours to be arranged. Basic electron optics, image formation and interpretation, construction and operation of the electron microscope, applications in physics, chemistry, and biology.

8517. *ELECTRON OPTICS AND ITS APPLICATIONS.* Credit 3 hrs. Fall. Prereq., Physics 225 (Physics 215 advised but not required). Electron beam formation, Gaussian dioptrics and aberrations of electron lenses, application including cathode ray tube, electron microscope, beta ray spectrometer, mass spectrometer.

COURSES IN OTHER DIVISIONS

Described in this section are certain courses prescribed for undergraduate students in engineering, given in the College of Arts and Sciences or other divisions of the University, as indicated below.

MILITARY TRAINING

The University requirement in military training (see p. 18 above and the *Announcement of the Independent Divisions and Departments)* may be satisfied:

(a) by four terms of satisfactory work in the Department of Military Science and Tactics (Military Science 11, 12, 21, and 22); or

(b) by four terms of satisfactory work in the Department of Air Science (Air Science IA, IB, IIA, IIB); or

(c) by four terms of satisfactory academic work in the Department of Naval Science (Naval Science 101, 102, 201, and 202). (According to their respective contractual

agreements with the Navy, Regular and Contract NROTC students are committed to continue in the NROTC program for four years.)

Students who have had service in the armed forces may be exempt from the requirement in military training. For exemptions on other grounds, consult the *Announcement of the Independent Divisions and Departments.*

Advanced courses of two years in military science and tactics and air science are elective and may qualify students for appointments as Second Lieutenants in the Regular Army or Air Force, U.S. Army Reserve, or the U.S. Air Force Reserve.

The Department of Naval Science offers a four-year course of training which may qualify students for appointments as Ensigns in the Regular Navy or Naval Reserve or as Second Lieutenants in the Marine Corps or Marine Corps Reserve.

Academic credit of three hours a term may be earned in the advanced courses in military science and tactics and air science. This credit may be applied toward any of the free electives offered in the curricula of the College of Engineering. Students who complete the four-year course in naval science are given University credit for twenty-four hours of college work. At present, net credit toward degree requirements of the various schools of the College of Engineering is as follows: School of Mechanical Engineering, at least 9 hours; School of Electrical Engineering, 12 hours; School of Chemical and Metallurgical Engineering, 12 hours; School of Civil Engineering, 12 hours; Department of Engineering Physics, 6 hours.

Further details concerning the courses offered in military training may be obtained in the *Announcement of the Independent Divisions and Departments.*

PHYSICAL EDUCATION

The University requirement in physical education (see p. 18 above and the *Announcement of the Independent Divisions and Departments)* may be satisfied by four terms of satisfactory work in the Department of Physical Education. For this purpose Physical Education 1, 2, 3, and 4 are available to men, and Physical Education 52A, 52B, 53, and 54, to women. Additional courses in physical education are described in the *Announcement of the Independent Divisions and Departments.*

ARCHITECTURE

REGIONAL AND CITY PLANNING

(In cooperation with the School of Civil Engineering)

700. *HISTORY OF CITY PLANNING.* Spring term. Credit three hrs. Open to graduates and upperclassmen. The history of the planning of communities from ancient times to the present. Lectures, assigned readings, and examinations.

710. *PRINCIPLES OF CITY AND REGIONAL PLANNING.* Fall term. Credit three hrs. Open to graduates and upperclassmen. A review of the basic influences in the development of cities. A general view of the theory and accepted practice of city and regional planning, including a study of the social, economic, and legal phases. Lectures, assigned readings, and examinations.

711. *CITY PLANNING PRACTICE.* Spring term. Credit three hrs. Prerequisite, Course 710. The procedures and techniques of gathering and analyzing data for municipal planning studies. The selection and integration of data for use in planning. Practical application of the theories of city planning. Office practice. Lectures, assigned readings, reports.

717. *LEGAL ASPECTS OF PLANNING.* Spring term. Credit two hrs. Prerequisite, Course 710. Technical and legal aspects of preparing and administering zoning ordinances. Examination of other legal problems in planning, including subdivision

control, official map procedure, regulation of roadside development, and building and housing codes.

718. *PLANNING DESIGN.* Fall term. Credit eight hrs. Limited to graduate students and, by permission, to seniors. Students are assigned a series of design problems as a means of introduction to the basic principles of large-scale site planning. Lectures, discussions, and group and individual criticism.

720. *FIELD PROBLEM IN URBAN PLANNING.* Fall term. Credit eight hrs. Group study of an existing community and the preparation of a general plan for its future development. Investigation of population trends, economic base, and regional influences. Land use analysis, and studies of traffic flow, recreation facilities, housing conditions, school and public building locations, automobile parking, public transportation, and other elements of the community. Preparation of recommendations for carrying out the general plan. Lectures, discussions, field trips, preliminary and final reports.

CHEMISTRY

105–106. *GENERAL CHEMISTRY.* Throughout the year. Credit three hrs. a term. Chemistry 105 is prerequisite to Chemistry 106. For those students who will take more chemistry, it serves as a prerequisite to the more advanced courses. Open to those who have had or have not had high school chemistry. May be elected by students who do not intend to take more chemistry. Lectures, T Th 9, 10, or 12. Combined discussion-laboratory period, M W F or S 8–11, M T W Th or F 1:40–4:30.

The important chemical principles and facts are covered, with considerable attention given to the quantitative aspects and to the techniques which are important for further work in chemistry.

113–114. *GENERAL CHEMISTRY AND INORGANIC QUALITATIVE ANALYSIS.* Throughout the year. Credit four hrs. a term. Chemistry 113 is prerequisite to Chemistry 114. Open to those who have offered high school chemistry for entrance. Required of all students in the School of Chemical and Metallurgical Engineering: lectures M W F 8; one three-hour combined discussion-laboratory period, T or Th 8–11, W or F 10–1, or W or F 1:40–4:30. Spring term: lectures, M W 8; two three-hour combined discussion-laboratory periods, T Th 8–11, W F 10–1 or W F 1:40–4:30. A general study of the laws and concepts of chemistry based upon the most common elements and application of the theory of chemical equilibrium to the properties and reactions of ions of the common elements and their separation and detection in solution.

224. *INTRODUCTORY QUANTITATIVE ANALYSIS.* Either term. Credit four hrs. Prerequisite, Chemistry 201 or 113–114. Required of candidates for the degree of B.Ch.E. Lectures, M W 10. Laboratory, T Th 1:40–4:30, F 1:40–4:30 and S 9–12 (either term), T Th 8–11 (fall term only).

A study of the fundamental principles of gravimetric and volumetric analysis, with practice in stoichiometry, and the analyses of a variety of substances by volumetric, gravimetric, and colorimetric methods.

301. *INTRODUCTION TO ORGANIC CHEMISTRY.* Fall term. Credit two hrs. Prerequisite, Chemistry 106. For students in engineering. Lectures W F 9.

A brief survey of the principal classes of organic compounds, their industrial sources, manufacture, and utilization.

307–308. *INTRODUCTORY ORGANIC CHEMISTRY.* Throughout the year. Credit three hours a term. Prerequisite, Chemistry 106 or 114. Qualitative analysis is desirable but not required. Chemistry 307 is prerequisite to Chemistry 308. Chem-

istry 311–312 must be taken with Chemistry 307–308. Required of candidates for the degree of B.Ch.E. Lectures, M W F 9.

A systematic study of the more important classes of carbon compounds, reactions of their functional groups, methods of synthesis, relations, and uses.

311–312. *INTRODUCTORY ORGANIC LABORATORY.* Throughout the year. Credit two hrs. a term. Chemistry 311 or 305 is prerequisite to Chemistry 312. Must be taken with Chemistry 307–308. Required of candidates for the degree of B.Ch.E. Laboratory lecture for all sections, T 11. Laboratory, T Th 1:40–4:30 or F 1:40–4:30 and S 9–12 (either term) or T Th 8–11 (fall term only).

Laboratory experiments on the preparation of typical organic compounds, their properties, reactions, and relations.

401. *INTRODUCTION TO PHYSICAL CHEMISTRY.* Fall term. Credit three hrs. Prerequisites, Chemistry 106, Mathematics 163, 183, or 193, and Physics 117. For students in electrical engineering. Lectures, T Th 9; recitation, S 9 or 11.

A brief survey of physical chemistry.

402. *INTRODUCTION TO PHYSICAL CHEMISTRY.* Spring term. Credit two hrs. Prerequisite, Chemistry 106. Prerequisite or parallel courses, Mathematics 163, 183, or 193, and Physics 117. For students in civil and mechanical engineering. Lectures, W F 9. Engineering physics students and others who wish to obtain three hours credit for the course will also meet M 9.

A brief survey of physical chemistry.

403–404. *INTRODUCTORY PHYSICAL CHEMISTRY.* Throughout the year. Credit three hours a term. Prerequisite, Chemistry 224 and 308. Mathematics 163, 183, or 193, and Physics 118. Chemistry 403 is prerequisite to Chemistry 404. Required of candidates for the degree of B.Ch.E. Lectures, M W F 9.

A systematic treatment of the fundamental principles of physical chemistry. The laws of thermodynamics and of the kinetic theory are applied in a study of the properties of gases, liquids and solids, thermochemistry, properties of solutions, and equilibrium in homogeneous and heterogeneous systems. Chemical kinetics and atomic and molecular structure are also studied.

411–412. *INTRODUCTORY PHYSICAL LABORATORY.* Throughout the year. Credit two hours a term. Prerequisite or parallel course, Chemistry 403–404 or 407–408. Chemistry 411 is prerequisite to Chemistry 412. Enrollment may be limited. Required of candidates for the degree of B.Ch.E. Laboratory, M T W Th or F 1:40–4:30; lecture-recitation, Th or F 12.

Selected quantitative experiments both in classical and in modern physical chemistry. Experiments in homogeneous and in heterogeneous equilibria, electrochemistry, calorimetry, reaction kinetics, spectroscopy, and other branches of physical chemistry.

ECONOMICS

103. *MODERN ECONOMIC SOCIETY.* Either term. Credit three hrs. Open to a limited number of freshmen. Fall term, M W F 8, 9, 12, 2 or 3; T Th S 8, 9, 11. Spring term, M W F 8, 9; T Th S 9.

A survey of the existing economic order, its more salient and basic characteristics, and its operations.

104. *MODERN ECONOMIC SOCIETY.* Either term. Credit three hrs. Prerequisite, Economics 103. Fall term, M W F 8, 9; T Th S 9. Spring term, M W F 8, 9, 12, 2 or 3; T Th S 8, 9, 11.

A continuation of Economics 103.

EDUCATION

Educ. 7. *READING IMPROVEMENT PROGRAM.* Either term. Noncredit. Prerequisite, all students are required to take the Cooperative Reading Test at times to be announced. Fall term, M W 9, 10, 11, 1, 2; or T Th 8, 9, 10, 11, 1. Spring term, M W 9, 10, 11; or T Th 8, 9, 10, 11. Laboratory: two half-hour periods a week to be arranged. Fall program is reserved for selected freshmen. Spring program is open to all registered students. Enrollment limited. Stone 105.

Designed to increase efficiency in reading rate and comprehension. Principles and techniques of good reading are explained, demonstrated, and practiced in class. The laboratory is equipped to provide an opportunity to practice good reading habits under controlled conditions.

ENGLISH

111–112. *INTRODUCTORY COURSES IN READING AND WRITING.* Throughout the year. Credit 3 hrs. a term. Open to freshmen; students who have prepared in English abroad must take a proficiency test in the fall for admittance. English 111 is prerequisite to 112. The aim of this course is to increase the student's ability to communicate his own thought and to understand the thought of others.

ENGLISH FOR FOREIGNERS

The following two courses are offered by the Division of Modern Languages. Students will be placed in these courses only after having taken the proficiency test given by the Department of English.

102. *ENGLISH FOR FOREIGNERS.* Fall term. Credit six. hrs. Prerequisite, placement by the instructor. Hours to be arranged.

211. *ENGLISH FOR FOREIGNERS.* Fall term. Credit six hrs. Prerequisite, a satisfactory proficiency examination. Hours to be arranged.

GEOLOGY

113. *ENGINEERING GEOLOGY.* Either term. Credit three hrs. only. Students who have had Geology 101–102 or 115 may take 113 for one hour credit. Lectures: fall term, M W 11; spring term, T Th 9. Laboratory, M W or T Th 2–4:30.

Provides a geologic background so that the engineer will be competent to adapt his work to conform with the limitations imposed by geologic conditions.

712. *METALLURGICAL RAW MATERIALS.* Fall term. Credit three hrs. For second-year students in metallurgical engineering. Lectures, M T Th 9.

The properties, occurrence, associations, distribution, and economic aspects of the commercially important ore, refractory, and fluxing materials that enter metallurgical operations.

HISTORY

165–166. *SCIENCE IN WESTERN CIVILIZATION.* Throughout the year. Credit three hrs. a term. Prerequisite, one year of college science. History 165 or consent of the instructor prerequisite to History 166. M W F 11.

A survey of the development of science in its relation to the main currents of European and American civilization from classical antiquity to the present day.

INDUSTRIAL AND LABOR RELATIONS

SURVEY OF INDUSTRIAL AND LABOR RELATIONS (ILR) 293. Credit three hrs. Either term.

A survey for students in other divisions of the University. An analysis of the major problems in industrial and labor relations: labor union history, organization, and operation; labor market analysis and employment practices; industrial and labor legislation and social security; personnel management and human relations in industry; collective bargaining; mediation and arbitration; the rights and responsibilities of employers and employees; the major governmental agencies concerned with industrial and labor relations.

MATHEMATICS

161. *ANALYTIC GEOMETRY AND CALCULUS.* Either term. Credit three hrs. Prerequisite, three years of college preparatory mathematics. Hours to be arranged.

Plane analytic geometry through conics. Differentiation and integration of polynominals with applications to rates, maxima, volumes, pressures, etc.

Courses 161–162–163 represent a standard three-term calculus sequence, presenting the main ideas and techniques of the calculus and analytic geometry; the material is so arranged that the first two terms (161–162) provide a reasonably complete introduction to the subject.

This sequence is not intended as preparatory to more advanced courses in mathematics, although admission to such courses can be obtained following this sequence by special permission. Students majoring in mathematics or in those physical sciences where mathematics is extensively used or who have special mathematical competence should elect the 161–182–183 sequence instead.

162. *ANALYTIC GEOMETRY AND CALCULUS.* Either term. Credit three hrs. Prerequisite, Mathematics 161. Hours to be arranged.

Differentiation and integration of algebraic, trigonometric, logarithmic, and exponential functions, with applications. Related topics, including polar coordinates, parametric equations, and vectors.

163. *ANALYTIC GEOMETRY AND CALCULUS.* Either term. Credit three hrs. Prerequisite, Mathematics 162 or 182. Hours to be arranged.

Infinite series, solid analytic geometry, partial derivatives, and multiple integrals.

182. *ANALYTIC GEOMETRY AND CALCULUS.* Either term. Credit three hrs. Prerequisite, a grade of 80 or more in Mathematics 161. Hours to be arranged.

Topics similar to those of Mathematics 162.

183. *ANALYTIC GEOMETRY AND CALCULUS.* Either term. Credit three hrs. Prerequisite, a grade of 80 or more in Mathematics 182. Hours to be arranged.

Topics similar to those of Mathematics 163.

201. *ELEMENTARY DIFFERENTIAL EQUATIONS.* Either term. Credit three hrs. Prerequisite, Mathematics 163. Fall term, M W F 8, T Th S 11. Spring term, M W F 12, 2.

Solution of ordinary differential equations by analytic and numerical methods.

607. *APPLIED MATHEMATICS FOR ELECTRICAL ENGINEERS.* Spring term. Credit three hrs. Prerequisite, Mathematics 163. Hours to be arranged.

Primarily for undergraduates. Complex numbers, linear differential equations, linear algebra and matrices, solution of algebraic and transcendental equations, Fourier series.

609–610. *HIGHER CALCULUS.* Throughout the year. Credit three hrs. a term.

Prerequisite, Mathematics 201 or 607 or the equivalent. First term prerequisite to second. T Th S 9, 10.

Primarily intended for students who do not have sufficient time available for mathematical electives to permit taking the five-term sequence 612–616 and who do not have sufficient mathematical maturity to take 621–622. Partial differentiation, multiple and line integrals, Fourier series, partial differential equations, vector analysis, complex variables, calculus of variations, Laplace transforms. Emphasis is placed on a wide range of formal applications of the calculus rather than on the logical development.

612. *METHODS OF APPLIED MATHEMATICS.* Spring term. Credit three hrs. Prerequisite, Mathematics 183. Students not majoring in physics or engineering physics must secure the consent of the instructor. T Th S 10.

This constitutes the first semester of a five-semester sequence. Roughly half of the course will be devoted to ordinary differential equations with emphasis on setting up and discussing physical problems. The remainder will cover an introduction to vector analysis, in preparation for Physics 225. Further topics in vector analysis (in particular, curvilinear coordinates) will be treated in 613, while additional material in differential equations will be taken up in 614.

613–614. *METHODS OF APPLIED MATHEMATICS.* Throughout the year. Credit three hrs. a term. Prerequisites, Mathematics 612. First term prerequisite to second. T Th S 10.

Functions of several variables. Line, surface, and volume integrals. Change of variables and Jacobians. Integral vector calculus with emphasis on curvilinear coordinate systems. Infinite series with numerical terms. Infinite series of functions. Uniform convergence. Power series. Fourier series and integrals. Applications to ordinary differential equations. Theory of matrices.

615. *METHODS OF APPLIED MATHEMATICS.* Fall term. Credit three hrs. Prerequisite, Mathematics 614 or consent of the instructor. M W F 12.

For graduate students and qualified undergraduates. A one-semester course in functions of a complex variable, stressing technique rather than rigor, and serving also as preparation for Mathematics 532. The elements of the theory and other topics, including conformal mapping and linear transformations, singularities, analytic continuation, Riemann surfaces, asymptotic expansions.

616. *METHODS OF APPLIED MATHEMATICS.* Spring term. Credit three hrs. Prerequisite, Mathematics 613 and 614. M W F 12.

Partial differential equations, special functions, calculus of variations.

621–622. *MATHEMATICAL METHODS IN PHYSICS.* Throughout the year. Credit four hrs. a term. Prerequisite, a good knowledge of the techniques of the calculus, such as given by 609–610, and at least two years of general physics. First term prerequisite to second. T W Th F 12.

For mature students who wish to acquire a wide background of mathematical techniques in one year. Lectures and problem work designed to give the students a working knowledge of the principal mathematical methods used in advanced physics. Topics include infinite series, Fourier series and integrals, Laplace transforms, complex variables, calculus of variations, matrices, integral equations, and eigenvalue problems.

MODERN FOREIGN LANGUAGES

FRENCH

101. *ELEMENTARY COURSE.* Either term. Credit six. hrs. Students who have previously studied any French must taken the qualifying examination before register-

ing for this course. Fall term, drill, M T W Th F S 8, 9, 10, 11, or 12 and lecture, M W 8, 10, or W F 12 or T Th 8. Spring term, drill, M T W Th F S 8, 9, 10, or 11 and lecture, M W 11 or T Th 9.

102. *ELEMENTARY COURSE.* Either term. Credit six hrs. Prerequisite, French 101 or its equivalent. Students who have not completed French 101 (except those currently enrolled in French 101) must take the qualifying examination before registering for this course. Either term, drill, M T W Th F S 8, 9, 10, 11, or 12; and lecture: fall term, M W 8 or 11 or T Th 9 or 2; spring term, M W 8, 10, W F 12, or T Th 8.

201. *INTERMEDIATE READING COURSE.* Either term. Credit three hrs. Prerequisite, a satisfactory qualifying examination or French 103. Fall term: M W F 9, 10, 12, T Th S 10. Spring term: M W F 9, 10, 12.

Reading of texts of established literary quality. The purpose is double: to increase reading facility, knowledge of vocabulary and idiom, and to develop methods and habits of critical appreciation of a foreign literature. The class discussion is conducted mainly in French.

203. *INTERMEDIATE COMPOSITION AND CONVERSATION.* Either term. Credit three hrs. Prerequisite, a satisfactory qualifying examination or French 103. Fall term, M W F 2, T Th S 8 or 10. Spring term, M W F 9, 12 or 2, T Th S 8 or 9.

Guided conversation, grammar drill, and oral and written composition. Emphasis is placed upon increasing the student's oral and written command of French.

204. *INTERMEDIATE COMPOSITION AND CONVERSATION.* Either term. Credit three hrs. Prerequisite, French 203. M W F 12.

Continuation of the work of French 203, with especial attention to accurate and idiomatic expression in French. Oral and written drill.

GERMAN

101. *ELEMENTARY COURSE.* Either term. Credit six hrs. Students who have previously studied any German must take the qualifying examination before registering for this course. Fall term, drill, M T W Th F S 8, 9, 10, 11, or 12 and lecture, M W 9 or 11, or T Th 11 or 2. Spring term, drill M T W Th F S 8 or 9, and lecture, T Th 12.

102. *ELEMENTARY COURSE.* Either term. Credit six hrs. Prerequisite, German 101 or its equivalent. Students who have not completed German 101 (except those currently enrolled in German 101) must taken the qualifying examination before registering for this course. Fall term, drill, M T W Th F S 8 or 9 and lecture, T Th 12. Spring term, drill, M T W Th F S 8, 9, 10, 11, or 12 and lecture, M W 10 or 11, or T Th 9 or 2.

203–204. *COMPOSITION AND CONVERSATION.* Throughout the year. Credit three hrs. a term. Prerequisite, qualification in German. Course 203 or consent of the instructor is prerequisite to Course 204. T Th S 12.

RUSSIAN

101. *ELEMENTARY COURSE.* Either term. Credit six hrs. Fall term, drill M T W Th F S 9, 10, or 12 and lecture M W 2 or T Th 11. Spring term, drill M T W Th F S, 8 or 11 and lecture T Th 2.

102. *ELEMENTARY COURSE.* Either term. Credit six hrs. Prerequisite, Russian 101 or its equivalent. Fall term, drill M T W Th F S, 8 or 11 and lecture M W 10. Spring term, drill M T W Th F S 9, 10, or 12 and lecture M W 2 or T Th 11.

SPANISH

101. *ELEMENTARY COURSE.* Either term. Credit six hrs. Students who have previously studied any Spanish must take the qualifying examination before registering for this course. Fall term, drill, M T W Th F S 8, 9, 10, 11, or 12 and lecture, M W 2 or T Th 9 or 12. Spring term, drill, M T W Th F S 8 or 12 and lecture, M W 9 or T Th 10.

102. *ELEMENTARY COURSE.* Either term. Credit six hrs. Prerequisite, Spanish 101 or its equivalent. Students who have not completed Spanish 101 (except those currently enrolled in Spanish 101) must take the qualifying examination before registering for this course. Fall term, drill, M T W Th F S 8, 9, 11, or 12 and lecture, W F 12 or T Th 10. Spring term, drill, M T W Th F S 8, 9, 10, or 11 and lecture, T Th 11 or W F 12 or T Th 12.

PHYSICS

121. *INTRODUCTORY ANALYTICAL PHYSICS.* Fall term. Credit three hrs. Co-requisite, registration in Mathematics 161. Entrance physics is desirable but not required. Lecture, T 9, 11, or 2. Two recitations a week and one laboratory period every other week, as assigned. Primarily for students in the College of Engineering.

Introductory mechanics: kinematics of particles, dynamics, statics, energetics and conservation laws, special motions. The laboratory work consists of measurements illustrative of the above topics.

122. *INTRODUCTORY ANALYTICAL PHYSICS.* Spring term. Credit three hrs. Prerequisite, Physics 121; co-requisite, registration in Mathematics 162, 182, or 192. Lecture, T 9, 11, or 2. Two recitations a week and one laboratory period every other week, as assigned. Primarily for students in the College of Engineering. Preliminary examinations will be held at 7:30 p.m. on March 8, April 12, and May 10.

Kinetic theory of gases; mechanics of gases; introductory thermodynamics. Electrostatic phenomena and introduction to electric circuits. The laboratory work consists of measurements in mechanics and in geometrical optics.

123. *INTRODUCTORY ANALYTICAL PHYSICS.* Fall term. Credit three hrs. Prerequisites, Physics 121, 122 and co-registration in Mathematics 163, 183, or 193. Lecture, Th 9 or 11.

An introductory survey of the laws of electric and magnetic fields. Review of the electrostatic field, magnetic fields of steady currents, induced emfs, dielectrics, and magnetic properties of matter. The laboratory work will include experiments in electrical measurements.

124. *INTRODUCTORY ANALYTICAL PHYSICS.* Spring term. Credit three hrs. Prerequisite, Physics 123 (or equivalent). Lecture, Th 9 or 11.

An introductory study of wave motion with emphasis on the properties of electromagnetic waves. Interference, diffraction, dispersion, scattering, and polarization of waves. Selected topics from the fields of atomic, solid state, and nuclear physics dealing with wave-particle experiments, optical and X-ray spectra, radioactivity, and nuclear processes. The laboratory work will include experiments in physical electronics and wave optics.

125. *INTRODUCTORY ANALYTICAL PHYSICS.* Fall term. Credit three hrs. Prerequisites the same as those for Course 123. Lecture, T 9 or 11.

The main topics will be the same as those listed in Physics 123, but their treatment will be more analytical and somewhat more intensive.

126. *INTRODUCTORY ANALYTICAL PHYSICS.* Spring term. Credit three hrs. Prerequisite, Physics 125 or consent of the instructor. Lecture, T 9 or 11.

The range of topics is similar to those listed under Course 124, but coverage is more intensive.

127. *INTRODUCTORY ANALYTICAL PHYSICS.* Fall term. Credit three hrs. Prerequisites the same as those for Course 123. Lecture, T 9 or 11.

The subject matter of electricity and magnetism listed in Physics 123 will be covered at a level sufficiently advanced to stimulate students of superior competence and interest.

128. *INTRODUCTORY ANALYTICAL PHYSICS.* Spring term. Credit three hrs. Prerequisite, Physics 127 or consent of the instructor. Lecture, T 9 or 11.

Topics similar to those of Physics 124. The treatment will be designed to meet the needs of students who intend to pursue more advanced courses in physics.

210. *ADVANCED LABORATORY.* Either term. Credit three hrs. a term. Prerequisites, Physics 208 and 209 or the equivalent. Laboraory, M T or W Th 1:40–4:30.

About seventy different experiments are available among the subjects of mechanics, acoustics, optics, spectroscopy, electrical circuits, electronics and ionics, heat, X-rays, crystal structure, solid state, cosmic rays, and nuclear physics. During the term the student is expected to perform four to eight experiments, selected to meet his individual needs. Stress is laid on independent work on the part of the student. Required for physics majors.

214. *ATOM, NUCLEAR, AND ELECTRON PHYSICS.* Spring term. Credit three hrs. Three lectures. Prerequisites, Physics 124 and Mathematics 607 (E. E. curriculum) or the equivalents. Primarily for students in electrical engineering.

Elements of nuclear and atomic structure, fundamentals of quantum theory; electronic processes with special reference to the electrical properties of metals, semiconductors, and insulators; elements of nuclear processes.

216. *PHYSICAL OPTICS.* Spring term. Credit two hrs. Prerequisites, Physics 124 or 207 or their equivalent. Lectures, T Th 9.

Huygens' and Fermat's principles with applications to geometrical optics, wave properties, velocity of light, interference phenomena, Fraunhofer and Fresnel diffraction with application to image formation, polarization of light, double refraction, optical activity, and other topics as time permits.

225. *ELECTRICITY AND MAGNETISM.* Fall term. Credit three hrs. Prerequisite, Physics 123 or 208 and 209 or their equivalent (209 may be taken concurrently). Lectures, T Th S 9 or 11. There will be two preliminary examinations to be held in the evening.

Electrostatic and electromagnetic fields, polarization of dielectic and magnetic media, Maxwell equations, plane electromagnetic waves.

226. *ELECTRICITY AND MAGNETISM.* Spring term. Credit three hours. Prerequisite, Physics 225. Lectures, T Th S 12.

242. *ANALYTICAL MECHANICS.* Spring term. Credit three hrs. Prerequisites, Physics 208 and 209 and Mathematics 201, or their equivalents. M W F 11 and an optional period to be arranged.

Analytical mechanics of material particles, systems of particles and rigid bodies; planetary motion, stability of orbits; collisions; Euler's equations, gyroscopic motion; Lagrange's equations; relativistic mechanics.

243–244. *ATOMIC, MOLECULAR, AND NUCLEAR PHYSICS.* Throughout the year. Credit three hrs. a term. Prerequisite, Physics 225 or consent of instructor. M W F 10.

The fundamental particles of physics, statistical physics, the concepts of quantum

mechanics, atomic structure and spectra, the periodic table, molecular structure and the chemical bond, properties of nuclei, nuclear reactions, interaction of radiation with nuclei, behavior of high-energy particles, and cosmic rays.

254. *ELECTRONIC PROPERTIES OF SOLIDS AND LIQUIDS.* Spring term. Credit three hrs. Prerequisite, Physics 243. M W F 9.

A semiquantitative introduction to the concepts of modern solid state physics, covering lattice structure, lattice defects, lattice vibrations, cohesive energy, elastic and inelastic properties, electron theory of metals and semiconductors, dielectric and magnetic properties.

020. *INFORMAL STUDY IN PHYSICS.* Either term. Credit one to three hours a term. Hours to be arranged. Reading or laboratory work in any branch of physics under the direction of a member of the staff. Permission of the staff member under whose direction the work is to be done must be obtained before registration.

475. *CLASSICAL MECHANICS.* Fall term. Credit four hrs. Prerequisite, Physics 242 or its equivalent. T Th S 11 and S 12.

Lagrange's equation, with applications to particle accelerators; linear vector spaces and small vibrations; Hamilton's equations; variational principles; transformation theory, and Hamilton-Jacobi methods; periodic systems, perturbation methods, introduction to wave motion and scattering.

476. *ELECTRODYNAMICS.* Spring term. Credit four hrs. Prerequisite, Physics 225 or its equivalent. T Th S 11 and S 12.

Introductory potential theory; Maxwell's equations and their meaning; quasi-static problems; energy and momentum of the field; waves in space and in guides; radiation and scattering; special relativity.

PSYCHOLOGY

207. *BASIC PROCESSES: PERCEPTION.* Fall term. Credit three hrs. Prerequisites, Phychology 101, elementary statistics, and three further hours of psychology. Lectures, M W 12. Laboratory, Th 2–4.

An account of the ways in which the normal human adult registers and apprehends his environment. The experimental study of psychophysical correlation, or space, motion, objects, and events, and the relations of perceiving to everyday behaving and thinking.

PUBLIC SPEAKING

201. *PUBLIC SPEAKING.* Either term. Credit three hrs. Not open to freshmen. M W F 8, 9, 10, 11, or 12; T Th S 8, 9, 10, 11.

Designed to help the student communicate his ideas and convictions effectively in oral discourse. Study of basic principles of expository and persuasive speaking, with emphasis on finding, evaluating, and organizing materials, and on simplicity and directness in style and delivery. Practice in preparing and delivering speeches of various types on current issues and in chairmanship; study of examples; conferences.

The services of the Speech Clinic are available to those students who need remedial exercises. Students whose native language is not English must obtain special clearance from the Department before registering.

FACULTY AND STAFF

DEANE W. MALOTT, A.B., M.B.A., LL.D., D.C.S., President of the University.
DALE RAYMOND CORSON, Ph.D., Dean of the College and Professor of Physics.
JOHN F. McMANUS, C.E., Assistant Dean of the College.
DONALD H. MOYER, B.S., M.A., Director of the Office of Student Personnel.
JEANETTE POOR, B.S., Librarian.

VICTOR EMANUEL VISITING PROFESSORSHIP

OLAF ERIK HANS RYDBECK, M.Sc. D.Sc., 1957–1958 (fall term).
BALTHASAR VAN DER POL, D.Math. and Physics, Ph.D., 1957–1958 (spring term).
THEODORE VON KÁRMÁN, M.E., Ph.D., 1958–1959 (spring term).

SCHOOL OF CIVIL ENGINEERING

NEPHI ALBERT CHRISTENSEN, B.S.C.E., M.S.C.E., Ph.D., Director of the School and Professor of Civil Engineering.
ANNETTE M. DIMOCK, Administrative Assistant, School of Civil Engineering.

EMERITUS PROFESSORS

SAMUEL LATIMER BOOTHROYD, M.S., Professor of Astronomy, Emeritus.
WALTER L. CONWELL, C.E., Professor of Highway Engineering, Emeritus.
CARL CRANDALL, C.E., Professor of Civil Engineering, Emeritus.
SOLOMON CADY HOLLISTER, B.S., C.E., D.Eng., Sc.D., Professor of Civil Engineering, Emeritus.
JOHN EDWIN PERRY, B.S. in C.E., Professor of Railroad Engineering, Emeritus.
ERNEST WILLIAM SCHODER, B.S., B.S. in Min., Ph.D., World War Memorial Professor of Experimental Hydraulics, Emeritus.
HERBERT HENRY SCOFIELD, M.E., Professor of Testing Materials, Emeritus.
ROMEYN Y. THATCHER, C.E., Professor of Civil Engineering, Emeritus.
PAUL HALLADAY UNDERWOOD, C.E., Professor of Civil Engineering, Emeritus.
CHARLES LEOPOLD WALKER, C.E., Professor of Sanitary Engineering, Emeritus.

PROFESSORS

DONALD J. BELCHER, B.S.C.E., M.S.E., Professor of Civil Engineering.
PAUL P. BIJLAARD, C.E., Professor of Mechanics.
MARVIN BOGEMA, B.S., M.C.E., Professor of Civil Engineering and Professor in Charge of Applied Hydraulics Laboratory.
HARRY D. CONWAY, B.Sc. (Eng.), M.A., Ph.D., Professor of Mechanics.
GORDON P. FISHER, B.E., D.Eng., Professor of Civil Engineering.
JOHN C. GEBHARD, C.E., Professor of Civil Engineering and Head of the Department of Construction Engineering and Administration.
TAYLOR D. LEWIS, B.S.E., C.E., Professor of Civil Engineering and Head of the Department of Transportation Engineering.
ARTHUR J. McNAIR, B.S., M.S., C.E., Professor of Civil Engineering and Head of the Surveying Department.

GEORGE WINTER, C.E., Ph.D., Professor and Head of the Department of Structural Engineering.

ASSOCIATE PROFESSORS

BENGT BROMS, C.E., M.S., Ph.D., Associate Professor of Civil Engineering.
CHARLES DONALD GATES, B.A., M.S., Associate Professor of Civil Engineering.
WILLIAM L. HEWITT, A.B., B.C.E., M.C.E., Associate Professor of Civil Engineering and Head of the Department of Engineering Drawing.
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